BIOMETRIC EVIDENCE IN THE PROBLEM OF THE PAIRED LIMBS OF THE VERTEBRATES.

BASHFORD DEAN.

FROM early development onward a fish is accurately poised in its living medium. Its long axis in a position of rest remains normally horizontal, in spite of the most varied changes in the size and shape of the fish's body and the shiftings and differentiation of its component parts. To preserve an accurate balance under conditions of rest as well as under the strain of the most active movement implies obviously a delicate adjustment of the morphological elements of the animal to the physical ones. And as the latter are relatively constant it follows that the acute strain in the evolution of the fish's body, both in ontogeny and phylogeny, has fallen upon the morphological elements. These, then, become subject to form changes, to position changes, and, most important, to physiological changes, to enable them to fulfill the mechanical requirements of habitat. To what degree the results are successful in adapting the vertebrate body to aquatic living can best be understood by comparison of the "area curves" and "entering

angles," not only among fishes of different groups but between fishes and cetaceans ; for in these practically the same " lines " and " entering angles " [1] obtain.

From a physical standpoint we conclude, therefore, that the position of the gravity center of the animal during different stages of growth plays an important rôle in connection with its ever-increasing body length, and that special organs of balancing, *i.e.*, fins, will in their development be subject *par excellence* to the mechanical needs in shifting which the changing position of the gravity center and increasing body length demand.

From this standpoint, then, one can attack the long-troubled problem of the origin of the vertebrate limbs. Not, however, with the aim of solving it indisputably, — for this I firmly believe can be done only by the paleontologist, — but rather for the purpose of finding a probable clue to the labyrinthine confusion in latest morphological studies ; for the voluminous conclusions of Braus, following Gegenbaurian teachings, and supported by Semon in his recent work on Ceratodus, — *cf.* also the related work of Klaatsch, — are vigorously denied by the newer phases of the fin-fold theory of Dohrn, Mollier, Rabl, and others, which in turn are in the latest time criticised by Fürbringer. In short, there is at present a deadlock in the discussion as to the mode of origin of the limbs of the vertebrates which cannot yet be loosened by orthodox embryological methods. Perhaps it will be bettered when a greater number of forms will have been examined, or when we shall have a clearer knowledge of the processes of accelerated and retarded development. Perhaps, on the other hand, to take a more somber view, it will never be adequately loosened by study of embryonic structures, since these may have been so modified during phylogeny as to mask hopelessly their true homologies. For the discussion has to a large measure narrowed itself down to the interpretation of embryological details, which if given fixed morphological weight become of great importance in theoretical discussion, but which are relatively valueless if

[1] The entering angle terminates with "wonderful uniformity" at 36 per cent of the total length of the animal, whether teleost or cetacean. *Cf.* especially H. DeB. Parsons, *Trans. Amer. Soc. Engineers*, vol. ix, 1888. 17 pp., 7 pls.

viewed as nothing more than adaptations to recent physiological needs. Thus, as an example, a tangle of nerves and blood vessels on the tailward side of a fin lobe of a shark may be either an important morphological condition as vestige of an ancestral, paddle-shaped, ceratodont fin, *e.g.*, as Braus maintains, or it may be nothing more than a newly developed condition to enable muscles and nerves to get in better touch with an enlarging and specializing margin of the fin, — which may indeed in its growth be developing from stage to stage special embryonic and larval movements. Again, the emancipation of nerves, vessels, and muscles from the basis of an embryonic fin may be the result either of the migration of a gill bar element in the Gegenbaurian sense, or merely of a purely local change in the requirements for balancing the constantly growing animal. For the center of gravity may shift as the body grows, and the fin (in sharks functional even when the "larva" is growing within the egg case) may thus have to move forward and backward as mechanical needs demand.

"But," the Gegenbaurian would maintain, "*our* theory is supported by fin migration. Of course we are willing to grant that the record is obscured by cenogensis, but we have still morphological evidence that the ventral fin migrates backward, and that the pectoral is relatively stationary, its girdle resembling the adjacent branchial arches. And we believe, moreover, that the mechanical fin needs, which have been noted above, are of the utmost importance, since it is in response to them that the ventral fin has traveled backward and that the pectoral fin has retained, relatively, its primitive position. Indeed, the very perfect segmental character of the ventral fin can be best explained in terms of a continued hindward migration, for the ventral is not the more steadfast and more primitive fin."

Now, it has long seemed to me that such a line of argument could be invalidated if it could be shown that during the growth of the individual the fins responded to their mechanical requirements in just the opposite way ; that is, that the ventral fin was *not*, and that the pectoral fin *was*, the migrating element. And the present paper has grown out of an attempt to trace,

and to this end by biometric methods, the actual stages in the development of the paired fins in accordance with their physical requirements. Assuming, for example, a complete series of a form in which the limb characters can be favorably examined, say a shark,[1] in stages ranging from adult to embryos in which the paired limbs are just appearing as distinct structures, we can then determine by measurement what change occurs from stage to stage in the position of the gravity center (with reference to the total length of the animal), and by similar measurement of the fins in similar terms we can ascertain what ratio these measurements bear to the possible shifting of this center. For all will admit that the fins themselves, as light and delicate structures, can in their growth play little direct part as a *cause* of the changing position of the center of gravity, and that their migration, forward or backward, is rather an outcome of the shifting of bulkier organs, — muscles, brain, viscera, sense organs. We can therefore conclude that by such a system of measurements one can obtain evidence as to whether the ventral fins migrate backward, *i.e.*, in terms of the total length of the individual, and show the correlation in growth with the pectorals which the Gegenbaurian theory demands; or whether, on the other hand, it is the ventrals which are constant, and resemble the dorsal fins, while pectorals play the part of the mobile and specializing members.

The following notes are based upon a cestraciont shark,[2] a form particularly interesting from the standpoint of morphological conservatism, since there is reason to believe that it has been little modified since Carboniferous times. And the measurements are recorded of sixty individuals ranging in length from 330 mm. to 14.5 mm. For this careful and laborious computation I am much indebted to my former student, Prof. C. H. Brookover, who made it the beginning of a research

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[1] Better, of course, would be sets of many genera and species; but as long as these are lacking, we may base conclusions as to essential characters upon the ontogeny of a single form.

[2] *Heterodontus japonicus* Macleay. The embryos were collected during the writer's visit to Japan, 1901, thanks to the many privileges which he enjoyed at Misaki as guest of the Imperial University of Tokyo.

upon the general problem of limb migration. He was, however, unable to carry out his plans, and he generously turned over to me his measurements for use in the present paper.

DETAILS OF DATA.

Straight specimens were selected for measurement. Gravity center was determined in terms of the total length [1] by balancing the specimen either on a knife-edge or within the delicate tips of curved forceps. By this simple method the limit of error was found to be surprisingly small, estimated by repeated tests at about 1 per cent. In the measurements individual variations are taken into account, since it was found that a more advanced embryo is sometimes smaller in size and variable slightly in proportions, and in preparing the table of averages as plotted in Fig. 1 this source of error has been largely counterbalanced by the use of guide points representing the average of several (usually four) successive individuals. All measurements are computed in percentage of the total length of the specimen, and are estimated from the snout tip. The landmarks whose relative position is computed are indicated graphically in the present Fig. 1, *i.e.*, anterior margins of pectoral, of ventral, and of dorsal fins, and posterior margins of pectorals and ventrals. Of the latter margin the functional (dermal) one is alone considered.

THE RESULT OF THIS ANALYSIS.

The *center of gravity* is found to shift forward (about 5 per cent of the total length) in the earlier embryos (embryos from 27 mm. to about 6 mm.), in later stages (up to embryos of 200 mm.) backward to the extent of about 8 per cent of the total length. In well-grown specimens the position of the gravity center remains practically unchanged.

The *pectoral fin* undergoes conspicuous changes : from the time it can be distinctly differentiated from the ventrals it

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[1] The transverse plane in which the center occurs was alone determined; its more accurate position *within this plane* has evidently no bearing upon the present problem.

TABULATED MEASUREMENTS OF FINS AND GRAVITY CENTER OF CESTRACION EMBRYOS.

(BY C. H. BROOKOVER.)

			FROM SNOUT TIP TO					
	TOTAL LENGTH.	CENTER GRAVITY.	ANT. MARG. PECT. FIN.	POST. MARG. PECT. FIN.	ANT. MARG. VENT. FIN.	POST. MARG. VENT. FIN.	FIRST DORSAL.	SECOND DORSAL.
	mm.	%	%	%	%	%	%	%
1	14.5	—	31 +	38 —	—	—	—	—
2	15	—	32	40	—	—	—	—
3	15	—	27	35 —	—	—	no spine	no spine
4	20.5	—	26	38 +	42 +	49 +	39 no spine	63 — no spine
5	21.5	—	25 —	32 +	41 +	48 +	37 + no spine	56 —
6	24 —	—	24 +	31 —	37 +	44 —	35 +	58 +
7	24	—	28 —	37 —	45 —	52 ÷	40 —	62 +
8	26.5	—	26 +	32 +	40 +	48 —	33 —	53 —
9	26.5	31	27 —	33 —	41 +	48 +	34	57
10	27	28	24 +	30	37	44 +	34 —	53
11	27	26 —	25 —	31 —	39 —	45 +	33	53
12	27.5	—	24 +	31 +	38 +	46 —	32	57
13	28	—	21	28	32	39	30 bent	50 bent
14	31	—	23	31	39	45	32	55
15	31	—	25	31	37	43	32	50
16	32.5	—	24	30	38	41	29	50
17	34	—	22	28	34	40	31	50
18	34.5	—	22	29	34	40	28	49
19	35	—	24	31	38	45	30	51
20	35	—	20	26	30	38	29	48
21	35	—	22	28	34	40	29	50
22	37.5	—	23	29	31	45	29	50
23	38	—	22	28	39	46	30	50
24	39	—	22	29	39	44	29	51
25	39	—	21	27	35	43	27	50
26	39	—	21	27	34	40	27	48
27	40	—	20	26	32	40	28	48
28	40	—	21	29	36	42	28	50
29	40	26	21	27	35	41	27	48
30	40.5	—	20	26	35	40	28	48
31	41	—	22	27	35	43	26	47
32	41	—	21	29	34	41	29	50
33	41.5	—	20	26	30	39	26	47
34	42.5	—	22	28	36	42	28	50
35	43	—	22	29	39	44	29	49
36	43	26	21	26	34	40	25	45
37	44.5	26	20	26	34	39	29	50
38	44.5	—	21	27	37	43	27	49
39	45	—	22	27	36	43	27	48
40	46	—	20	26	34	38	27	48
41	46.5	31	22	27	35	42	27	48
42	50	25	20	26	37	41	27	46
43	50	24	21	25	32	38	24	43
44	50	25	20	26	33	40	25	47
45	51	—	20	26	33	40	25	50
46	55	25	19	25	35	41	26	46
47	59.5	24	18	24	31	39	23	50
48	60	23	21	27	34	40	25	47
49	61	25	18	25	34	41	25	48
50	62	23	19	26	34	41	27	47
51	66	26	19	23	33	40	24	46
52	72	25	17	26	33	41	24	51
53	73	26	18	30	37	42	27	50
54	81	25	19	29	36	43	26	52
55	82	24	19	30	37	43	27	52
56	105	27	19	30	37	46	27	53
57	187	31	17	42	37	50	27	57
58	197	32	18	42	41	53	30	57
59	280	30	18	39	41	53	31	59
60	330	30	18	43	41	53	29	59

increases greatly in size, measured antero-posteriorly, from
6 per cent of length to about 24 per cent, its anterior and
posterior margins undergoing somewhat different fates. The
anterior rim of the fin passes forward, suddenly in earlier stages,
slowly in later ones, altogether a distance of over 12 per cent
of the total length, a distance considerable enough, I take it,
to entail important adaptive changes in the structures of the
encroached-upon region, especially in view of the fact that this
fin margin grows forward as the gravity center passes back-
ward. (*Cf.* also *infra, rc* the continuous hindward growth of
the outer gill slits.) Interesting in this connection is the
slight variant in embryos of about 80 mm. ; here, the gravity
center shifting a little forward, the anterior fin margin passes
backward, thus indicating a nice adjustment in the mechanical
relations between them. In a general way the advance of the
anterior rim of the pectoral is at the same pace as the retreat
of the center of gravity. The behavior of the hinder rim of
the pectoral shows a less close adjustment to the gravity center.
In early stages this fin rim passes forward (about 11 per cent
between stages of 15 mm. to 56 mm.) to about the transverse
plane of the center of gravity ; thereafter, however, it grows
hindward, gradually increasing the distance from the gravity
center (11 per cent) (and from the anterior fin rim (total, 24 per
cent)). By this noteworthy hindward growth it comes in the
older stages to overlap somewhat the anterior rim of the
ventral fin.

The *ventral fin* is conservative in its position during growth :
measuring about 6 per cent of the total length in earlier stages,
it increases to but 12 per cent in latest ones, a gain in per-
centage of but 6 per cent as against 18 per cent in the pec-
toral. Like the pectoral, the entire fin passes slightly forward
in younger stages, then slightly backward. The anterior rim
remains almost fixed with reference to the body length, the
posterior passing slightly backward to a degree corresponding
almost exactly with the shifting of the gravity center. Thus,
in an embryo of about 80 mm. the center of gravity is 18 per
cent in advance of this rim, in one of 115 mm. 19 per cent,
in one of 145 mm. 19 per cent, of 187 mm. 19 per cent, a

correspondence so close that we can interpret it only in terms of cause and effect.

The *dorsal fins* are even more conservative in position than the ventrals.   In the first place they maintain practically the same relative distance from one another, measured from the anterior rim of the fins[1]: thus, in a specimen of 21 mm. the interval measures about 23 per cent, of 40 mm. about 22 per cent, of 60 mm. 23 per cent, of 82 mm. 25 per cent, of 105 mm. 26 per cent, of 197 mm. 27 per cent; in other words, between the two fins there is but a slight variation in the interval (say, 5 per cent of the entire length) in stages widely different in size (*e.g.*, measuring between 20 and 200 mm.).   In general, however, we note that the growth of the anterior rims of first dorsal and ventral are indicated by parallel lines, and similarly the growth of the anterior rim of the second dorsal and the posterior rim of the ventral.

Summary.

The foregoing characters yield what seems to me convincing evidence that the pectoral fin is subject to changes with respect to the gravity center, *i.e.*, physical changes, which cause it to become more highly specialized than the ventral fin, and that the latter is conservative, after the fashion of the unpaired fins.   The result of biometric data, it will be seen, confirms strikingly the views of the fin-fold theorists, most clearly expressed in this particular regard by Wiedersheim in his "Gliedmassenskelet."   On the other hand, the present study yields *no evidence that there has ever been a migration of the fins in the Gegenbaurian sense ;* thus, we find no reason to believe that the ventral fin is a structure which has shifted its position from in front hindward ; it is indeed in about the same position fore and aft in the adult as in early embryos (20 mm.).   It is important, furthermore, that the only fin (leaving anal and caudal out of discussion) whose anterior margin passes forward is the pectoral, since with this condition is correlated the fact that this

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[1] In the younger stages the measurement was made from the actual most anterior point of the fin ; in the later, when a spine appears, from the point where the anterior fin rim, if produced, would intersect the dorsal-most line of the body.

rim alone is in advance of the gravity center. Thus, as this center passes backward, the posterior margin of the ventral fin is found to follow it *pari passu*, and, as effecting a counter balance, like equal weights placed in opposite scale pans, the anterior rim of the pectoral passes headward.

Again, contrasting the embryos shown drawn to scale in Fig. 1, and referring now to the position of the external gill openings, we note that there is a marked tendency for these openings to pass backward. In the earlier specimens all are widely interspaced and the last is well in front of the fore rim of the pectoral ; in the next embryo the openings are drawn together, altogether somewhat tailward ; and in the latest, as far at least as to the second opening, the series have taken a position hindward of the rim of the pectoral.

More concretely (measurements taken from the specimens) :

GILL OPENING.	PERCENTAGE OF LENGTH FROM SNOUT TIP.			PERCENTAGE OF TAIL-WARD MIGRATION.
	Stage 1.	*Stage 2.*	*Stage 3.*	
I	11 %	13 %	16 %	5 %
V	19 %	19 %	23.5 %	4.5 %

In other words, as far as these openings are concerned, and with them the *outer part* at least of the gill canal, it is evident that in the older stages a definite migration has taken place, to a degree that, in terms of the total length of the animal, the gill openings come to occupy a position in the body wall which is largely behind that of the earlier stages. Numerically considered, the interval between gill openings I and V is about 8 per cent of total length in stages 1 and 3 ; but in the latter the region of the gill openings is nearly 5 per cent farther tailward ; therefore, in this stage the openings occupy a position in the body surface which is about five-eighths new, *i.e.*, never before occupied by gills. From this it follows that *the gill region, at least in its outer part, shows no affinity during proportional growth with the neighboring region of the pectoral fin. In fact, from an early stage onward, they are evidently growing in opposite directions.*

If, now, we figure the matter up, we find that the distance the gill openings pass tailward (contrasting embryos varying from about 20 to 300 mm.), added to the distance which the anterior rim of the pectoral passes headward, makes the considerable sum of 20 per cent of the length of the animal. And from this it follows that there occurs in this region a process of "shortening up," which is surely enough to account for the presence of anastomosing vessels, blended muscle bands, plexus of nerves, and "collectors." The presence of such complicated structures,[1] especially in the region of the anterior or posterior rim of a (pectoral) fin, is therefore to no little degree a product of the mechanical needs of fin migration.

COLUMBIA UNIVERSITY, October 17, 1902.

[1] Another complicating feature to be considered in this connection is the disposition of segments arising in the caudal region and growing cephalad. In the earlier embryos (15 to 20 mm.) the total number of segments behind the last gill arch is enclosed within a space measuring about 80 per cent of the entire length; later specimens (300 mm.) include the segments within a space of 76 per cent. The size of the embryo at which the formation of new segments ceases has not been determined in the present form, nor is it as yet ascertained in kindred forms.
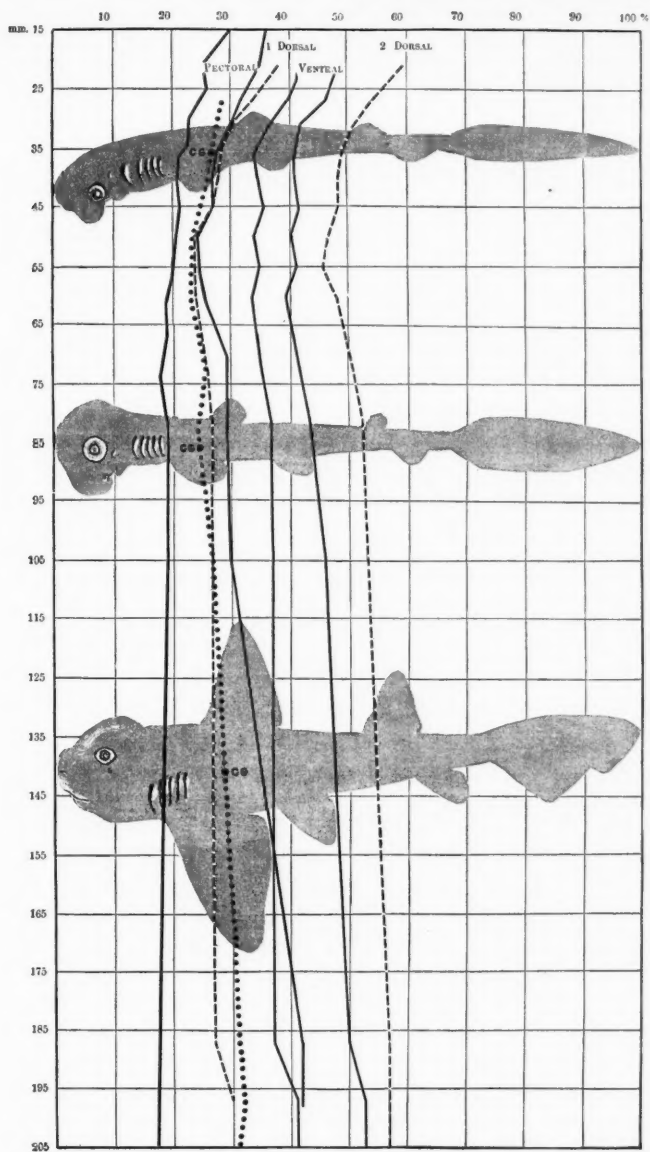
FIG. 1.—Cestracion at different growth stages. Tabulated measurements of sixty specimens indicating the position of the center of gravity and of the paired dorsal fins. In all specimens in the series the measurements are reduced to a common scale, *i.e.*, to a uniform length, which is here subdivided in percentage. The lengths of the specimens measured are indicated (in millimeters) in the vertical columns at the left. The landmarks in the different stages measured are connected by lines as follows: gravity centers, *C G*, by dots; fin margins of pectoral by heavy lines; of ventral by light lines; of dorsals by dashes. Outlines of stages of 35, 85, and 138 mm. are introduced to show these lines in their relative positions.

NOTICE OF INTERESTING NEW FORMS OF
CARBONIFEROUS FISH REMAINS.

C. R. EASTMAN.

THROUGH the kindness of Professor G. Hambach, of Washington University, St. Louis, a number of highly instructive Carboniferous fish remains have recently been brought to the writer's attention, two of which seem to possess considerable interest, and are therefore made the subject of the following notice. The first to which attention is invited is a remarkable specimen of Erismacanthus from the vicinity of St. Louis, now preserved in the private collection of Dr. Hambach. It is unquestionably the largest and at the same time most perfect spine belonging to this genus yet brought to light, and appears to be distinct from other described species. The second specimen noticed in the present paper yields new information regarding the dentition of *Campodus corrugatus*, and is from the Coal Measures of Winchester, Illinois.

Genus Erismacanthus M'Coy.

The two European and one American species of this genus that have been described are evidently closely related to Physonemus, but differ in that the spines are divaricated, the two branches extending in opposite directions in the same vertical plane. The imperfect ichthyodorulites known as Gampsacanthus, Lecracanthus, and Dipriacanthus are also of the same general nature, and all these bodies are interpreted by most authors as lateral head spines of presumably cochliodont or petalodont sharks. The occurrence of spines on either side of the head in sharks and chimæroids has been observed in a number of forms, such as in *Oracanthus armigerus* Traquair, from the Calciferous sandstone of Eskdale, Scotland, in the Permian *Menaspis armata*, and in Mesozoic cestracionts (Hybodus).

The Physonemus group of spines has been theoretically associ-
ated by Jaekel with the teeth of petalodonts, but this conjecture
has not been corroborated as yet by any direct evidence.

Very interesting stages of modification are displayed by the
group of Physonemus-like spines throughout their existence in
the Lower Carboniferous. The earliest and most primitive
forms of the typical genus are found in the Kinderhook, in
accompaniment with small forms of Stethacanthus. The two
or more species of Kinderhook Physonemi that are known are
of small size, attenuated, and quite destitute of surface ornamen-
tation. Erismacanthus is also represented in the Kinderhook
by two small, comparatively unornamented species, and it is
noteworthy that the branched condition is here rudimentary.
The Burlington species of Physonemus and Stethacanthus
display a marked increase in size, but the ornamentation is
feeble, and remains so throughout the stage represented by the
Keokuk Limestone. Stethacanthus seems to have attained its
maximum size in the Keokuk, as Physonemus did in the Bur-
lington (*P. gigas* N. and W.), a considerable falling off in this
respect being true of both genera in the St. Louis division.
The spines of Stethacanthus remain unornamented from their
first appearance in the Berea Grit of Ohio until their extinction
in the St. Louis Limestone, but those of Physonemus and Erisma-
canthus increase in complexity of ornamentation throughout the
Mississippian series, ultimately displaying great elaboration.
An inspection of the forms illustrated in Plate XXII of the
sixth volume of the *Illinois Palæontology,* or of the large spine
immediately to be described, will, we think, satisfy any one as
to the correctness of this latter statement and of the above
generalizations.

Erismacanthus formosus sp. nov. (Fig. 1).

DEFINITION. — A very large species, the spines attaining a total length
of at least 22 cm. Anterior branch stout, much produced, gently arched,
one side more or less flattened and provided with a double row of obtusely
conical denticles, the other smooth and convex, appearing as if imbedded.
Posterior spine considerably arched, prominently keeled, laterally com-
pressed, and bearing a double series of closely set denticles along the distal
half of the posterior margin. The posterior spine is relatively wide in its

basal portion, and tapers gradually toward the acuminate distal end ; its surface is ornamented with numerous longitudinal costæ which increase by bifurcation, and by rows of small, rounded or spiniform tubercles occupying the intercostal spaces, these being especially numerous on the broad basal portion of the spine, and extending also over the proximal portion of the anterior branch.

The above description is based upon the remarkable spine shown in Fig. 1, together with two or three imperfect specimens, all collected by Dr. Hambach from the St. Louis Limestone in the vicinity of St. Louis, Missouri. The large specimen has a total length of 21.5 cm., of which the anterior branch forms about four-sevenths and the posterior spine three-sevenths. It is nearly seven times the size of *E. maccoyanus*
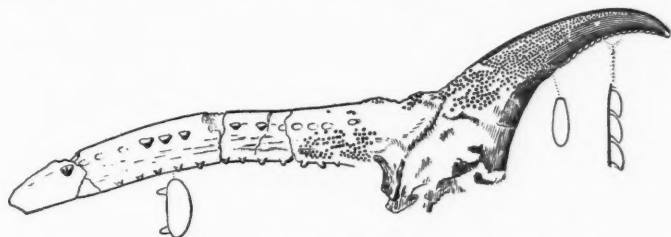
Fig. 1.—*Erismacanthus formosus* sp. nov. St. Louis Limestone; St. Louis, Mo. Lateral aspect of spine referred to the left side of the head, × ½. Cross sections are given of both branches at the points indicated by dotted lines, and three of the posterior denticles are shown slightly larger than the natural size.

St. J. and W., which accompanies it in the same formation, and twice that of *E. jonesi* M'Coy, the largest known European species. From both of these the present species differs not only in size, but also in the form of cross section and denticulations of the anterior branch, as well as in the general surface ornamentation. It appears improbable that the anterior branch was terminated by a cluster of denticles, but there is a double row of about twenty robust conical enameled bosses along the flattened face of this arm, which have evidently become obtuse through wear. This flattened face was probably entirely exposed, but there is reason to believe that the opposite, or more convex face, was buried in the integument. Its smooth surface presents the same appearance as the inserted portion of most fin spines, and betrays none of the usual indications of wear.

Obviously if this portion of the spine had projected freely, and were not anchored by insertion in the soft parts, it would have been not only a useless appendage but a positive hindrance to the creature, besides being constantly exposed to injury; but if we conceive of it as inserted in the integument in the same manner as the anterior prolongation of *Oracanthus vetustus*,[1] its function as a defensive organ and as a support for the posterior spine is readily understood. Evidence that this was a paired spine, and therefore not occupying a position in the median line of the back or of the head, is afforded by the fact that the exposed face of the anterior branch is turned so as to present the denticles toward the left-hand side; and the organ may therefore be interpreted as a lateral head spine belonging to the left side of the body.

The posterior spine is very similar to the single defenses of Physonemus, but is more strongly keeled and broader at the base. The distal half of the posterior margin bears a double row of closely set denticles resembling those of *E. maccoyanus*. The sides of the spine are occupied by numerous fine, smooth longitudinal costæ, of which about fifteen are to be counted along the line where the cross section shown in the figure is taken. The intercostal spaces, more particularly in the basal portion of the spine, are studded with numerous small tubercles, which are stellate in the unworn condition, and vary in shape between conical and spiniform. In many cases their summits are mucronate with the points reflected toward the basal portion of the spine, and the resemblance of these tubercles to certain types of placoid scales is very marked. It is probable that the imperfect spine illustrated in Pl. XXII, Fig. 3, of the sixth volume of the *Illinois Palæontology*, represents a young individual of this species.

Genus Campodus de Koninck.

This genus of cestraciont sharks is represented in the Coal Measures of North America by three species, one of which — *C. variabilis* (N. and W.) — is of importance as affording a

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[1] *Cf.* J. S. Newberry, *Trans. N. Y. Acad. Sci.*, vol. xvi (1897), p. 287, Pl. XXII, Fig. 3.

complete insight into the dentition of Orodus-like forms.   The
species described by Newberry and Worthen as *C. corrugatus*
has been known hitherto only by a few of the lateral teeth,

FIG. 2. — *Campodus corrugatus* (N. and W.).   Coal Measures ; Winchester, Ill.
Oral aspect of a portion of the symphysial dentition, × ¾.

and we have been without information regarding the symphysial
series.   One specimen, however, of the symphysial dentition
has recently come to light, and seems worthy of particular
description.

Campodus corrugatus (Newberry and Worthen) (Fig. 2).

The symphysial dentition of this species differs from that of *C. variabilis* in that the individual teeth are much more robust, less intimately fused with one another, and less differentiated in form from the lateral series; they are also apparently fewer in number than in the corresponding series of *C. variabilis*. All these characters point to the conclusion that as between the two species the latter is much more highly specialized and stands nearer to the line which gave off Edestus and other extremely modified cestracionts.[1]

The unique specimen of *C. corrugatus* shown in Fig. 2 exhibits five very robust teeth, which are recognizable by their peculiar form as having pertained to the symphysial series. Of how many teeth the entire series was constituted cannot be told, but owing to the large size of the teeth it is probable that the number was less than in *C. variabilis*, which has as many as thirteen. The apical extremities of the crowns have unfortunately all been broken away, and the bilateral symmetry of the series has been disturbed by mechanical agencies since the death of the creature, so that the teeth appear to succeed one another in spiral fashion, instead of being arched in a single plane. The apical portions of the crowns differ from those of *C. variabilis*, also, in that they are more elevated, and are inclined backward at a slight angle.

The coronal surface of each tooth is marked by a prominent transverse crest, from which numerous branches are given off approximately at right angles on either side. The anterior margins of the crowns are very prominently buttressed, an especially large projection occurring in the median line on both the anterior and posterior faces. Fig. 2 is photographed from a cast of the original specimen, which was obtained from Bates and Company's coal mine at Winchester, Illinois.

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[1] A detailed account of the dentition of Edestus and related forms is given in *Bull. Mus. Comp. Zoöl.*, vol. xl, No. 3, 1902.

THE MICROCOSM OF THE DRIFT LINE.

LÆTITIA M. SNOW.

In the spring of 1902 my attention was called to the extremely interesting life relations of insects along and around the line of drift thrown up by the waters of Lake Michigan, and a series of collections and observations were made between April 14 and May 31. The collections included one hundred and fourteen species, only fifty-one of which it was possible, with the means at hand, to identify. The specimens have, however, been preserved.

PHYSICAL FEATURES.

As with life everywhere, the physical features of the habitat are of great importance to the population. For instance, on Windsor Park beach, including the region north to Seventy-Second Street and south to the Steel Works, the forms were, as a rule, much more abundant than on the two beaches in Jackson Park. On the former beach the gradient is low and the sand smooth ; the water action is rather gentle, the insects stay when the water retreats, and the fine sand keeps them on the surface. At Jackson Park beaches, on the other hand, unless the water has recently been high and beyond the pebble zone, the collecting is poor. In the pebble zone the gradient is greater, the water action greater, and there is the possibility of the insects being washed out again into the lake. That the physical conditions of the beach account for the greater number of forms, and not the fact that collections at the two places were made at different times, may be proved by the fact that on the same day a pebble region of beach north of Windsor Park gave no results, while a smooth region yielded a number of forms.

Causes of Distribution.

The waves of the lake wash up great quantities of refuse, among which are numbers of insects. These animals may be either land or water forms; if the former, they have either come directly upon the shore, or have flown lakeward or been blown by an off-shore wind, and then been washed in, dead or dying. On account of the lake current moving southward along this region, specimens collected at Chicago may have come from points farther north (13). To this group of stranded land forms belong the ladybirds (Coccinellidæ), Chrysomelidæ, leaf-eating Scarabæidæ and Carabidæ, possibly the Elateridæ, Lucanidæ, and the Rhyncophora among the Coleoptera, the Lygæidæ and Pentatomidæ among the Hemiptera, the Hymenoptera, Neuroptera, Trichoptera, and Lepidoptera, — all of which are herbivorous. Also to this group belong some predaceous carabids and one roach. To the stranded water forms belong *Benacus griseus, Hydrophilus triangularis,* and two other water beetles.

These stranded forms may revive and depart, may serve as food for predaceous forms, or, if dead, fall to the share of the scavenger insects. The flies and ants are undoubtedly scavenger forms, and inhabit this region on account of the food supply. In this class I would also place a small carabid beetle (undetermined) which occurred for a while in great numbers under stones and débris, so as to preclude the idea of its having been stranded during migration. Several small beetles seem to have this scavenger habit; for example, three Staphylinidæ, some Scarabæidæ, and several Carabidæ. In this latter family we find some predaceous forms which seem to inhabit this region normally, to feed on the dying insects or on their destroyers; for example, several black forms (undetermined) and *Galerita janus.* The spiders are also predaceous, and feed on the flies, ants, and other small living insects. I might add that birds come in as a final factor and eat these various forms.

Order of Succession.

These insects do not come all at once, nor "hit or miss," but follow a fairly regular order of succession. It was seldom that the same form was dominant at two visits. Between April 14 and 21 very few insects were found, and no regular record was kept. The temperature was cool and the winds variable during that period. On April 25, after four days of S., S.W., and W. winds, followed by E. and S.E. winds, more forms appeared. Two days of strong (thirty to forty miles per hour) W. wind, followed by a S.E. wind, brought in a few forms on

Date.	Wind previous to Coll.			Wind, Day of Coll.		Temp. F.		Species.		
	Days.	Direction.	Av. Vel.	Direction.	Av. Vel.	Max.	Min.	New.	Old.	Total.
Apr. 25	2	W. to E.	19	S.E.	14	69	42	10	1	11
28	2	W.	37½	S.E.	15	61	48	3	0	3
May 2	2	E. to N.E.	20	S.W.	18	82	53	37	5	42
12	3	N.E.to E.to N.E.	21⅔	N.E.	10	56	43	27	10	37
16	7	N.E. to E.	16⅑	E.	10	61	48	6	19	25
23	2	S.W. to S.	12½	S.E.	10	77	61	13	19	32
27	2	W. to N.W.	15	N.E.	18	50	40	8	7	15
31	2	S.W.	17½	S.E.	15	75	60	2	14	16

(Data kindly furnished by the U.S. Weather Bureau, Chicago, Ill.)

April 28. All this time the temperature was cool, only once rising over 69° F. On May 2 a N.E. wind (twenty miles), preceded by a W. wind, brought in a good many forms, thirty-seven new species being found, besides several previously collected; the rising temperature (53°–82°) probably influenced the numbers. On May 12 twenty-five new species were found, besides an abundance of old ones. This rich supply was probably due to three days of W. and S.W. wind, followed by four days of N.E. and E. wind (averaging eighteen and three-fourths miles), which continued until May 16 with decreased velocity (thirteen and one-fourth miles), the temperature never exceeding 61° F. On this day only five new

species appeared, but numbers of old ones were found.   On May 23, after a warm period with S., S.W., and S.E. winds of low velocity, fourteen new species were collected, a few old ones appearing.   A N.E. wind on May 27, preceded by W. and N.W. winds of moderate velocity, brought in countless Colorado potato beetles and ten new species, the temperature dropping twenty degrees in two days.   On May 31 a S.W., followed by a S.E., wind brought only two new species, but a good many old ones occurred.   These results are placed on the preceding page in tabular form.

Dominant Forms.

The first form to predominate notably was *Chrysomela elegans* (May 2), while *Hippodamia parenthesis* came in a good second.   The little *Coccinella sanguinea* occurred throughout the season in about the same numbers, but absence of other forms made it at times the dominant species.   Black carabids occur also throughout, but never as dominant forms.   The next visit, May 12, showed *Diabrotica vittata* as the characteristic species, while of Chrysomela only a few specimens were found.   The small brown and black scavenger carabid was present in great numbers, and should probably be classed as the dominant form.   *Coccinella sanguinea* was numerous, as were also black carabids.   The following collection showed the Diabrotica, although not the characteristic species, still occurring in fair numbers ; the scavenger carabid seemed to be the most numerous form, with quantities of *Coccinella sanguinea*.   Of the larger forms Bombus sp.? and *Hydrophilus triangularis* were the most important.   This time (May 16) marked the first occurrence of *Galerita janus*, and the flies were first noted.   The various forms of Hemiptera occurred throughout the collecting trips, but were never dominant forms.   On May 23 the Colorado potato beetle (*Leptinotarsa decemlineata*) was the dominant form at Jackson Park.   This appears to have been the vanguard of the great "migration" which took place on, or just before, May 27 ; for on that date the beach at Cheltenham was nearly covered with the beetles,

dead, dying, or active.   In the latter case they had in many instances crawled up on stones and driftwood, until the surfaces of such articles were, in places, covered with them, sometimes two layers deep.   On May 31, however, very few live ones remained, and the total number of individuals was greatly diminished.   The form that approached the potato beetle in number on May 27 was the May beetle, or June bug (Lachnosterna sp. ?).

Besides those above mentioned, other forms occurred in greater or less abundance at different times, some running through the whole period, some starting late and continuing to the end, some starting early and disappearing.

MIGRATIONS.

Would the fact that certain forms culminated at certain times indicate that they simply reached the adult stage at that time, laid their eggs and disappeared, or that they were performing mass movements, broadly called "migrations"?   The great swarm of potato beetles on May 27 closely resembled mass movements recorded by many authors, in that the number was large and that the animals were found on the 27th and by the 31st had almost entirely disappeared, no new ones appearing.   If it were merely a general emergence, it is not likely they would have been found only along the lake front. This great washing up of one species recalls the predominance of crickets (*Nemobius fasciatus*) described by Needham (1).

Much has been written on this subject, both descriptive and theoretical, but the problems as to the "why" and "whither" of insect flights have never been solved.   The search for food has been suggested as the cause, and the suggestion has been accepted by many as at least a secondary factor.   In some cases over-production, followed by a scarcity of food, would seem a sufficient reason for the movement; as, for instance, the migrations of locusts, both in this and other countries (2, 3).   Certain examples of the flights of dragon flies point to the same cause (3, p. 509; 4; 10).   Kobelt (3) quotes Gätke as saying: "Es ist schon darauf hingewiesen worden,

dass auch die Bewegung der Nachtschmetterlinge meteorolo-
gischen Beeinflussungen unterworfen sind.   Diese Ansicht
stützt sich auf wiederholte Beobachtungen, nach welchen die-
selben unter gleichen Bedingungen wie die Vögel, und fast
immer zusammen mit diesen in ostwestlicher Richtung hier
vorbeiziehen "; which may be the key to the whole question.
As far as I am aware, no barometric observations have been
made directly on the subject of insect migration (15).

That a feeling of hunger is not alone a sufficient cause for
some of the direct flights recorded, is shown by the fact that
butterflies often continue in their path, over the very flowers
they use for food, only a chance one stopping on the way
(3, p. 509).   Also, if they simply spread out to find food,
the progression would be diffuse, directions inclined to be
random, and the advance a gradual one, as is the case with the
spring "dispersal through isolated individuals" of Danais (5),
which go north as the spring advances, various generations
taking part in the advance.

In many instances the direction of flight has not been noted,
but in Europe the general tendency seems to be from east to
west.   In our country, however, no such law appears to hold.
More attention has been paid to the consideration of whether the
animals, chiefly butterflies, flew against or with the wind, some
holding that the latter feat was impossible.   That it is at least
possible, has been shown by some direct observations (6, 7).

It has been suggested that, as in some cases the swarm was
composed of individuals of one sex (males), the flight origi-
nated in a search for mates ; but as the absence of females
can be explained in some instances by their wingless condition
(8, 1900, p. 13), while in most observations the sexes were nearly
equal in number, this cause may apparently be ruled out.

If they are then not necessarily merely drifted by the wind,
or impelled by immediate hunger or by the sexual instinct,
why do they follow such direct routes, fly with such apparent
aim, and often repeat the flight at intervals?   Walker attrib-
utes it to "a propensity to migrate" (8, 1901, p. 353), thus
throwing it back upon hereditary tendencies, while Kefer-
stein (4) adds to over-production and some aid from wind,

an unknown impulse to take a common migration.   Riley (5) makes the statement that "all insects acquire the migratory instinct when crowded together through excessive multiplication."   The probable response to meteorological influences has been noted.

Hancock (9) distinguishes between dispersal and migration in the statement, "Individuals of a species which effect a more or less regular periodical change in their habitat are truly migratory.   Migrations may be primary, consisting of local flights, such as movements by insects hatched in temporary regions, to which they confine themselves to passing to and fro, from point to point ; or secondary, as the repeated periodical changes of residence covering foreign fields, which naturally establishes a nomadic habit."   In addition to these distinctions it is suggested that the term "migrations" be confined to periodical changes of habitat resulting from the normal sequence of temperature and season, while such abnormal occurrences as the devastating swarms of Rocky Mountain locusts or irregular and unusual swarms, as in certain instances of butterfly, moth, and dragon-fly flights, be given, temporarily at least, the term "immigration."   Mr. Hancock's "primary migrations or local flights" would be simply dispersal flights of individuals or groups of individuals within their area of distribution.

Was the flight of Colorado potato beetles on May 27 a dispersal (or local) flight, diverted out of its course and driven lakeward by west winds, or was it a periodic migration ?   The predominance of other insects at various times was probably due to the spreading of groups of individuals by local flights : may not these local flights give some evidence of the dispersal paths of various species ?

Conclusion.

By whatever means the animals reached the region, — by migration or dispersal movement, — the life relations of the beach are not altered.   We have here a little community of food providers and food obtainers, whose population varies with the season, the wind (probably), the beach conditions,

and the relative abundance of the various forms. For example, we found (1) the occurrence was in succession ; (2) the population increased apparently at times when an offshore wind was followed by a lake breeze ; (3) it also increased with the temperature ; (4) the greatest numbers occurred on beaches of low gradient and smooth, fine sand ; (5) the abundance of scavenger forms depended upon the abundance of dead herbivorous and predaceous forms and other refuse ; (6) the abundance of predaceous forms depended upon the presence of the active scavenger and herbivorous and smaller predaceous forms.

LIST.

Of the one hundred and fourteen species collected fifty-one were identified, the whole collection being placed in the following orders and (where possible) families : —

Coleoptera, 75 : Carabidæ, 33 ; Scarabæidæ, 10 ; Chrysomelidæ, 9 ; Coccinellidæ, 7 ; Staphylinidæ, 3 ; Hydrophilidæ, 3 ; Cerambycidæ, 2 ; Elateridæ, 2 ; Silphidæ, 1 ; Histeridæ, 1 ; Halipidæ, 1 ; Lucanidæ, 1 ; Curculionidæ, 1 ; Calandridæ, 1.

Hemiptera, 11 : Pentatomidæ, 5 ; Lygæidæ, 2 ; Reduviidæ, 1 ; unknown, 1.

Diptera, 10 : Muscidæ, 5 ; Syrphidæ, 2 ; Phoridæ, 1 ; Tachinidæ, 1 (?) ; unknown, 1.

Hymenoptera, 9 : Apidæ, 4 ; Formicidæ, 1 ; Vespidæ, 1 ; Andrenidæ, 2 ; Tenthredinidæ, 1.

Lepidoptera, 3 : Arctiidæ, 2 ; Noctuidæ, 1.

Trichoptera, 2 : Phryganeidæ, 2.

Neuroptera, 2 : Chrysopidæ, 2.

Orthoptera, 1 : Blattidæ, 1.

Arachnida, 1 : (Lycosidæ ?)

Identified Species.

Name.	First Collected.	Dominant.	Last Collected.
Coleoptera		·	
Aphodius fimetarius	April 14–21	—	May
Hippodamia 13-punctata	25	—	12
Hippodamia parenthesis	25	—	2
Hippodamia convergens	25	—	2
Coccinella sanguinea	25	—	31
Cyllene pictus	May 2	—	—
Necrophorus marginatus	2	—	—
Coccinella 9-notata	2	—	31
Chrysomela elegans	2	2	31
Anatis 15-punctata	2	—	31
Agonoderus pallipes	2	—	23
Casnonia pennsylvanica	2	—	16
Drasterias elegans	2	—	12
Disonycha triangularis	2	—	—
Megilla maculata	12	—	27
Diabrottica vittata	12	12	16
Diabrottica 12-punctata	12	—	—
Leptinotarsa 10-lineata	12	27	31
Calosoma scrutator	12	—	31
Calosoma wilcoxii	12	—	31
Elaphrus ruscarius	12	—	—
Platynus sp.?	12	—	16
Galerita janus	16	—	23
Hydrophilus triangularis	16	—	31
Lucanus dama	23	—	27
Calosoma calidum	23	—	31
Euphoria inda	23	—	—
Phymatodes sp.?	23	—	—
Geopinus incrassatus	23	—	—
Lachnosterna sp.?	27	—	—
Cotalpa lanigera	27	—	—
Sphenophorus sp.?	27	—	—
Ligyrus gibbosus	31	—	—
Coptocycla aurichalcea	31	—	—
Hymenoptera			
Lasius brunneus	April 15–21 +	—	—
Polistes variatus	May 2	—	16
Prosopis sp.?	2	—	—
Augochlora sp.?	2	—	—
Bombus sp.?	12	—	27
Anthophora sp.?	27	—	—
Nomada sp.?	27	—	—

IDENTIFIED SPECIES (*Continued*).

NAME.	FIRST COLLECTED.	DOMINANT.	LAST COL- LECTED.
DIPTERA			
Syrphus torvos (?)	April 25	—	May 16
Lucilia cæsar	28	—	31
Scarcophagus georgiana.	May 23 on?	—	—
HEMIPTERA			
Oncopeltus fasciatus	May 2	—	—
Benacus griseus	16	—	—
LEPIDOPTERA			
Estigmene acræ (?)	May 27	—	—
Eyprepia (?)	27	—	—
ARACHNIDA			
Present throughout			

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STUDIES OF LOCALIZED STAGES OF GROWTH IN SOME COMMON NEW ENGLAND PLANTS.

JOSEPH A. CUSHMAN.

In the following are given some of the stages in detail found in a few of our common plants, and some general notes which may be safely drawn, and which may be useful in studying plants from this point of view. The cases given are not chosen as particularly striking ones, but are such as would come naturally under the notice of any one. In a following paper the writer hopes to present more striking examples from some of the less generally known plants now in the Botanic Gardens of Harvard University. The few given, however, will show the truth of the principle involved as well as more striking ones.

In a paper by Robert T. Jackson, "Localized Stages in Development of Plants and Animals," *Memoirs Boston Society of Natural History*, Vol. V, No. 4, 1899, this principle was worked out and applied to plants. It was there applied to shoots and various growths of trees almost exclusively. It is in the spirit of that paper that I have attempted this one, giving the results of my study of plants from this point of view. My thanks are due to Dr. Jackson for reading this in manuscript and for many suggestions.

The new point intended to be brought out here is the application of the principle of localized stages to the early spring growth of herbaceous plants. These are adult plants, not young plants or seedlings. The principle is also applied to the stages immediately preceding the flower.

The principle of localized stages in development, to quote from the above paper, is that, "throughout the life of the

individual, stages may be found in localized parts, which are similar to stages found in the young and the equivalent of which are to be sought in the adults of ancestral groups." This principle may be well demonstrated in a greater or less completeness in each of the following examples.

Viola pedata L. (Bird's-Foot Violet).

Under this species Gray's *Manual* gives, "leaves all 3–5-divided, or at the earliest only parted, the lateral divisions 2–3-parted, all linear or narrowly spatulate, sometimes 2–3-toothed or cut at the apex," thus recognizing the fact of the differences in the leaves but with no significance of the various forms or connection between them.

On April 18, 1902, a study was made of the leaves of this species in adult plants which were then well started. Among the larger and stronger plants it was found that the earliest leaves went back in the accompanying series usually to Pl. I, Figs. 10 or 11. After further search plants were found with the leaves on the outside of the rosette, similar to Figs. 9, 8, or 7. Noticing that the smaller plants seemed to be simpler or more primitive, attention was turned to them, and some small ones were found with the outside leaves going back to Fig. 6, and the smallest to Figs. 5 or 4. These were along a woods road in a somewhat dry, sandy place. In the middle of this road, where there was very little vegetation, were found plants evidently very young and weak, with the result that some were obtained with the simple leaves shown in Figs. 3, 2, and 1. That these were not seedlings was shown by the rootstock. They were probably weak plants of the preceding year.

In nearly all the stages shown many specimens were obtained of each stage, and in all cases enough to warrant the form as not abnormal. Where the outer leaves were most primitive the more complete were the stages before the typical leaves were produced in the center. Seedlings of this plant were not obtained, but the earliest of the stages given are very similar to corresponding ones of *Viola tricolor* L. in both young and adult. Later stages would naturally be specific. The seedling

would probably not repeat all of the stages given here, but the majority of them. The data here being fairly complete will be referred to again later.

Chelidonium majus L. (Celandine).

Seedlings of this plant were found at Arlington Heights in May, among the adult plants, and afforded a very convenient opportunity to study the relations of the two.

The leaves of the seedling after the cotyledons are developed as follows (Pl. II, Figs. 1, 2): First leaf usually slightly tri-lobed and trinerved; second leaf usually decidedly five-lobed and five-nerved; the third leaf is decidedly trilobed, with the median lobe notched, lateral ones entire or with one notch. From the third on, the trilobed character persists for a short period, the leaves becoming, later, three-pinnate, five-pinnate, and so on.

In comparing this with the first leaves of the adult plant when it starts from the ground in the spring, a striking like-ness is at once noted. In the plant shown in Pl. II, Fig. 3, the first leaf is exactly comparable to the second leaf of the seed-ling, and the second to the third of the seedling. The third leaf is like the three-parted one of the seedling, the fourth similar. The fifth is five-pinnate, and so on. In all cases where the first formed leaves were found on the plant, these comparisons were found to be true. It was especially noticeable in the plants found at Arlington Heights, which were on a sloping gravel bank with poorer nourishment than in other cases noticed in Cambridge. In this plant the early development in spring growth representing localized stages, and in the seedling representing direct development, not only show great similarity but may be exactly compared stage by stage.

Aquilegia canadensis L. (Wild Columbine).

The seedlings of this plant have the first nepionic leaves typi-cally trifoliolate, with the terminal leaflet having two well-marked notches and each of the lateral leaflets one less-marked notch

on the lower side.   By raising a number of the seedlings of this plant there was found a marked variation from the typical form.   In two cases the first nepionic leaves were trifoliolate, but both the terminal and lateral leaflets were entire, no sign of notches being present.   The second leaves in the two cases given were typical of the first of the other seedlings, thus showing that these two individuals were less accelerated in development than the others.   These two repeated the character of a trifoliolate leaf with entire edges, which is usually dropped out in the development of the seedling.

By comparison with the early spring growth of adult plants, the first leaves of some weaker individuals were trifoliolate and entire, as are those of the two seedlings noted above.   This is, then, not an accidental variation, but a true stage, which in the seedling is usually skipped by acceleration of development, and rarely appears there.   In several cases the first leaves were like the typical first leaves of the seedling.   This, then, shows two rates of acceleration, as it takes one longer to arrive at a certain stage than it does another.

A striking similarity is noticed in the leaves immediately preceding the flower.   At the base of the flower stalk the leaves are normal, but higher up the number of leaflets is reduced until, a short distance below the flower, there appears a trifoliolate leaf with notches varying considerably, some being like the typical first nepionic leaf of the seedling, others variously notched.   The majority, however, are like the seedling. The next leaf above usually drops out the notches and has an entire outline.   This can be directly compared to the earlier stage noted in two seedlings and in the average simple leaves of spring growth of the adult plant.   Just beneath the flower is often found a single leaf, entire and exactly comparable to the terminal leaflet of the trifoliolate leaf.   Thus at the flower the leaves retrace the steps which they went through in the early growth of the plant and in the reverse order.   This last stage — the simple leaf below the flower — is more primitive than anything that is found in the seedling, showing that localized stages may be used to fill in the steps which are crowded out by the acceleration of development in the seedling.

Ranunculus acris L. (Buttercup).

This species has the typical leaves three-divided, and the divisions considerably cleft and toothed, but the seedling starts off with fairly simple nepionic leaves (Pl. II, Fig. 4). Comparing the localized stages shown in the early spring growth with the direct development of the seedling, a great similarity is again noted. The plants were well started when observed, and weak growths had to be largely depended upon to show the stages. Pl. II, Fig. 5, shows a leaf of which one-half is comparable to the first nepionic leaf of the seedling. The other half is like the second nepionic. Here, then, is a leaf showing an acceleration of development in its two halves, — the half with two lobes being more accelerated than the other. This is often noted in compound leaves which are pinnate, — there being fewer leaflets on one side than on the other, — but is less often definitely shown in simple leaves. A first leaf of spring growth is figured, Pl. II, Fig. 6, which is comparable to the second nepionic leaf. The steps in complication of the lobes and nervation are shown in Figs. 7–9, and the seedling in its later development passes through similar stages.

Beneath the flower the leaves become more simple usually by four distinctly reverse, but often varied, steps. The lower one of the four has about the same number of divisions as Fig. 8, but is drawn out into linear divisions. Higher up is a leaf that may be compared to the second nepionic of the seedling, or to the leaf figured in localized development (Fig. 5), in that it has five lobes. It is, like the preceding, deeply cut and elongated. Above this is a three-lobed leaf of the same character and in its lobing comparable to the first nepionic leaf of the seedling. Just beneath the flower is usually a simple, elongated leaf, showing once more a localized stage in the adult plant more primitive than any of the stages shown in the direct development of the seedling.

This species is one which is usually well developed in the early spring, and these earlier and weaker forms are hard to find without careful searching. The first formed leaves quickly dry, curl, and then drop off.

Spiræa salicifolia L. (Common Meadowsweet).

This is not herbaceous, and the stem, unlike the others before noted, is woody, and the early spring growth is from the buds at the sides as well as new shoots from the ground. Such a lateral growth is figured, Pl. III, Fig. 3. The first leaf indications are mere bracts. The first of what may be called the true leaves is entire, lanceolate, with a simple median vein. This is the first in the series and the simplest. This seems to be a case like that noted under *Aquilegia canadensis*, where a stage is found simpler than that of the ordinary seedling first stage, as the first nepionic leaves of two species of Spiræa as figured by Lubbock are like No. 2 of Fig. 3. The second leaf is cuneate and tridentate, trinerved, the broadest part near the tip. The third leaf is five-dentate like the second nepionic leaf figured by Lubbock. The complexity of dentations increases and the broadest portion of the leaf moves from near the tip to near the base. The leaves become doubly serrate, but the tip holds the form of the second leaf given, throughout.

The spire formed by the flowers usually has one or more of the lower branches with more leaves than flowers, and here the reversal of the stages is well shown. Near the main stalk the leaves are typical, but moving distally along the branch they will be seen to lose little by little in the number of dentations. This keeps on until there are but three, as in the second leaf figured, and then there are several simple ones. The wedge shape, with its broadest part toward the tip, is not reassumed, but in dentations the stages are exactly reversed beneath the flowers.

Tanacetum vulgare L. (Tansy).

As far as was found, the seedling of this species has not been published, and therefore it is given in a little more detail than the others (Pl. III, Figs. 4 and 5).

Cotyledons glabrous, subfleshy; lamina oblong, obtuse, sessile. The first nepionic leaves are paired and vary considerably. As a whole they are spatulate, obtuse, and may be distally

toothed.   Ten seedlings in a single pot were compared as to
their first nepionic leaves as follows:

Both first leaves simple	2
One simple, one one-notched	1
One simple, one two-notched	1
Both one-notched	2
One one-notched, one two-notched	1
Both two-notched	3
	10

This crude table is enough to show the individual variation
of seedlings under the laws of acceleration of development
and the consequent necessity of making sure of the typical
stages.

The second pair of nepionic leaves have typically two lateral
teeth on each side in some cases, with more complicated forms
than this, but even in this case, so far as seen, only one of the
pair has the more complicated form, the other being typical.
The midrib begins to be distinct.

The next leaves are quite dissected and begin to decidedly
resemble the typical adult leaf.   It may have in the third pair
of nepionic leaves from three to seven or more lateral teeth on
each side, and these may also be divided or notched.

Among the adult plants at the very base in the first spring
growth, leaves may be found which repeat many of the simpler
conditions.   Fig. 6 is decidedly three-parted, much as the first
nepionic leaf in many ways, but less strikingly so than Fig. 7,
which is quite like the second nepionic leaf of the seedling.
Figs. 8 and 9 are like later seedling stages.   All of these leaves
are from the base of fresh spring growths.

The flowers of this plant are in a dense corymb, each portion
of which comes from the axil of a leaf.   The leaves in the
upper part become inconspicuous, but repeat, however, many of
the characters seen in the seedling and in the reverse order,
those immediately below the upper heads being like the first
and second nepionic leaves in the number of teeth and general
character.   This is exactly comparable to the principles of
senescence of the late Professor Hyatt, stages occurring in the
old age of the individual corresponding to stages passed through

in nepionic development, but in the reverse order of succession. He has shown this at length in his " Genesis of the Arietidæ," published in part as a paper of the Museum of Comparative Zoölogy of Cambridge, and as No. 673 of the *Smithsonian Contributions*. It is given more simply and concisely in a paper, " Cycle in the Life of the Individual (Ontogeny) and in the Evolution of its Own Group (Phylogeny)," *Proceedings of the American Academy of Arts and Sciences*, Vol. XXXII, No. 10, as well as in other papers. This case seems to be comparable in that it is a failure to develop the full characters of an earlier adult condition, due to the strength of the plant going into the production of flower and seed instead of developing leaves. The tip of the leaf in all cases repeats the tridentate character of the first nepionic leaf, both in the tip of the leaf proper and in the tips of all the divisions.

Viola tricolor L. (Pansy).

This plant is very seldom a perennial, but often comes up from the rootstock the second year. Such plants are easily obtained, and so exactly do the stages compare with the seedling that were it not for the rootstock and the absence of cotyledons the two might be easily mixed. The seedling is figured by Lubbock, *Seedlings* (1892), and in that and in seedlings examined the stages were exceedingly like those of the early spring growth from a rootstock. The reversal of these stages beneath the flower is seen with varying definiteness. The old single form known as heart's-ease seems to show this best. The number of notches decreases and the leaves return to the forms seen in the beginning, those directly beneath the flower being exactly like the first of the spring growth of the adult and the first nepionic (Pl. III, Figs. 1 and 2).

Rosa rubiginosa L. (Sweet Brier).

In this plant, perhaps, of those given here, the stages are most easily and completely seen. The seedling varies, having the first nepionic leaf single as in Pl. IV, Fig. 1, or it may be trifoliolate like the second leaf of Fig. 1, as in Fig. 2; in each case the

second nepionic leaf is trifoliolate, as well as several following ones. Then the number of leaflets increases to five, and in the full-grown plant becomes seven. In the first spring growth the first leaf, especially upon the lower or weaker parts of the plant, is very often trifoliolate, like the second nepionic leaf in all cases and like the first in some. In some cases, however, a simple leaf may be found, but rarely. When it does appear, it may be compared to the simple leaf seen in the first nepionic leaf of Fig. 1. After this trifoliolate leaf in the spring growth of the adult is one of five leaflets, then usually five leaflets until the flowering stage. Then the number drops by the same steps that it increases, but in the reverse order. Going toward the flower, leaves are encountered with five, then three leaflets, until finally just below the flower there is a simple one. Here, then, are repeated the exact steps by actual count of the stages of the seedling in the early spring growth, and as exact a reversal of the same stages beneath the flower. The same is true of *Rosa lucida* and other species (Pl. IV, Fig. 3).

Although these examples given might be multiplied almost without number, they will do to illustrate several general principles which may be drawn from them. The various conditions are more or less combined in any actual case, as they often are in such problems, but the effect of each may be noted nevertheless.

First, the relation between the occurrence of the earliest stages and the age of the plant. The plant coming up the second year, other conditions being the same, seems to be more primitive in its first characters than older and stronger plants. It therefore repeats more stages in arriving at the typical form than older individuals. The case of *Viola pedata* illustrated this, the young plants of the preceding year being the ones in which the earliest stages were noticed. In some plants, however, the typical leaf of the species is not reached for several years. The young trees of *Carya alba* Nutt., the shagbark hickory, have when very young — the second year, for example — only single and trifoliolate leaves, and it is some time before the number rises to five leaflets. The typical one of seven leaflets does not appear until quite a late period.

Weak individuals are more apt to show earlier stages than are more vigorous plants. They represent plants which are less accelerated in their development, not attaining the characters usual in plants of their age and other conditions. This is true whether the whole is weak or whether the growth comes from adventitious or weaker buds. The same is true of plants injured by outside agencies; for example, when the leaves are stripped by insects and a later growth put out from the weaker buds, before undeveloped.

Soil and moisture conditions come into play here. The poor sandy soil and lack of moisture mentioned in the first two examples given, shows its effect by producing weak individuals. Plants in poor, dry soil often repeat stages not seen in strong, vigorous plants in other places.

In studying these localized stages, especially in the early spring growth of herbaceous plants, some things must be especially looked out for. The first leaves which appear are often very small and would be overlooked unless they were being sought for especially. Many of these plants which start very early in the spring adopt the rosette form, and these first early leaves are hidden under the later ones. These small early leaves are usually delicate and soon wither and drop off, especially in rapid growth or where the rosette form is adopted. For these reasons many plants, even in early spring, may show no traces of the very early stages which they would have shown if examined a short time before. The surest way to find these first leaves is to notice where the plant is growing the year before and mark it in some way so that it may be looked for the following spring.

As shown, seedlings may vary considerably, and also these stages, so that to avoid errors there is necessary a knowledge of the seedling or allied ones, and of ancestral forms. By a close study of these localized stages and their variations — within limits — in many individuals, steps in the phylogeny may be determined which it would be impossible to fix in any other way. Many stages may be found in this way that in the acceleration of the seedling are crowded out of the record preserved there.

Coupled with a knowledge of the seedlings and of ancestral forms these localized stages may be used to great advantage in determining not only the phylogeny in a broad way, but the relations, especially to plants in the same genus or family. By comparing the character of the stages repeated and the acceleration with which they are gone through with, something may be learned of the position of the species in relation to others within the genus, according to the general principle that greater acceleration of development means a higher form. Comparison of seedlings of different species may also determine this to a considerable extent, but many seedlings of each species should be compared to get the relation of the variation. Thus from the seedlings of various species of Aquilegia raised and compared, a definite relation was noticed in regard to the relative difference in time of appearance of the same stage in different species. In this way localized stages, together with a comparative study of seedlings, may be made to yield profitable results in a field where there is otherwise very little data to depend on.

EXPLANATION OF PLATES.

Leaves are numbered in order of their development, except below the flower, — there, in the reverse order.   c = cotyledons.

Figures drawn from nature by the writer.

PLATE I.

Viola pedata L.

FIG. 1. First leaf of spring growth of plant one year old. Found in middle of old woods road-dry soil.   × 1½.

FIGS. 2, 3. Second and third leaves of same plant.   × 1.

FIGS. 4, 5. First leaves of spring growth of plants found at side of same road in slightly more favorable conditions.   Plants small and evidently weak.   × 1.

FIG. 6. First leaf of slightly stronger plant in same place.   × 1.

FIGS. 7–9. First leaves of decidedly stronger individuals in better situations.   × 1.

FIGS. 10, 11. First leaves of thrifty plants of more than one year's growth.   × 1.

FIGS. 12–14. Later leaves of same plants.   × 1.

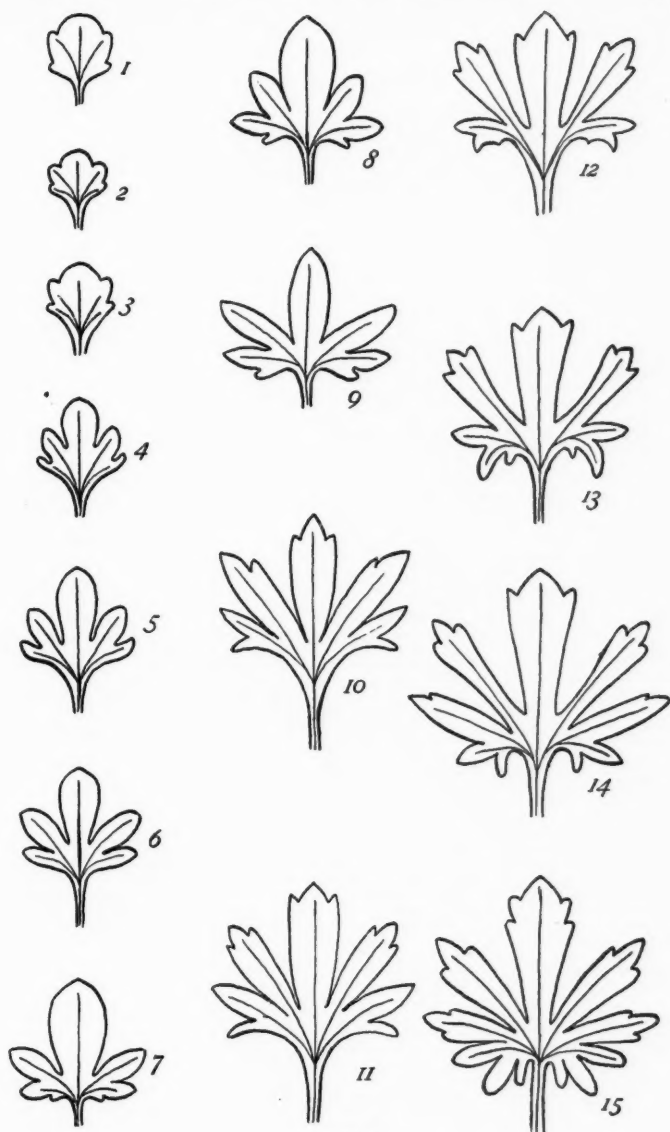FIG. 15. Most complex leaf noted in strongest and best developed plant.   × 1.

PLATE I.

PLATE II.

(All natural size.)

Chelidonium majus L.

Fig. 1. Seedling showing cotyledons and first and second **nepionic** leaves.

Fig. 2. Seedling as preceding, but showing also third nepionic leaf.

Fig. 3. Leaves of early spring growth. In sandy soil at Arlington Heights, Mass. 4th, 6th, and 8th leaves not shown—each like the one immediately preceding.

Ranunculus acris L.

Fig. 4. Seedling showing cotyledons and 1st, 2d, and 3d nepionic leaves.

Fig. 5. Simplest leaf found in an adult plant; first leaf of spring growth of weak plant. Two halves of leaf show difference in acceleration of development. Compare right half with 1 of Fig. 4; left half with 2 of same figure.

Fig. 6. First leaf of spring growth in weak plant. Compare with 2, Fig. 4.

Fig. 7. First spring growth of a weak shoot. Compare with 2, 3, Fig. 4.

Figs. 8, 9. Later stages in adult plant and complication of the network of veins.
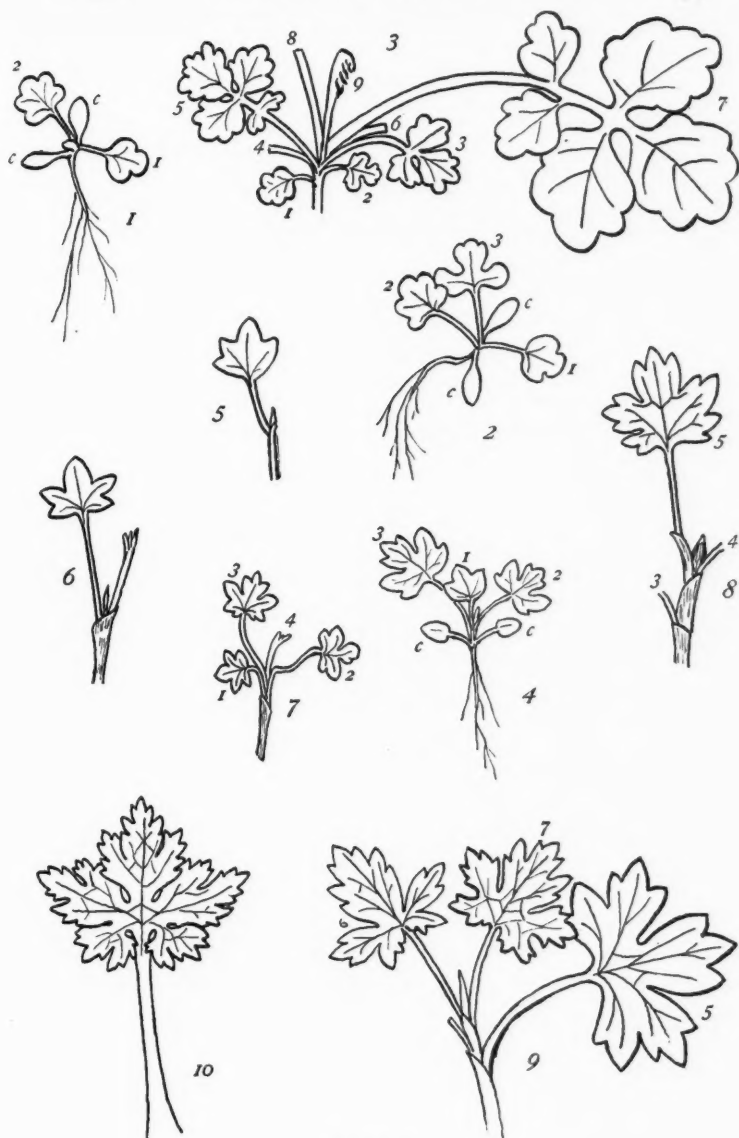
Fig. 10. Typical adult leaf.

PLATE II.

PLATE III.

(All natural size.)

Viola tricolor L.

FIG. 1. Stages in early spring growth from rootstock of preceding year.

FIG. 2. Stages below flower.   Numbered in reverse order of development for comparison with preceding.

Spiræa salicifolia L.

FIG. 3. Growth from lateral bud on plant of previous year.   Bract-like leaves at base not numbered.

Tanacetum vulgare L.

FIG. 4. Seedling with cotyledons and typical pair of first nepionic leaves.

FIG. 5. Seedling with second pair of nepionic leaves also.

FIGS. 6–10. Leaves found near the base of adult plants in spring growth. Compare 6 and 7 with 1 and 2 of Figs. 4, 5.

FIG. 11. Simplest leaf to be found after early spring growth has withered. Very complex when compared with Figs. 6–9.
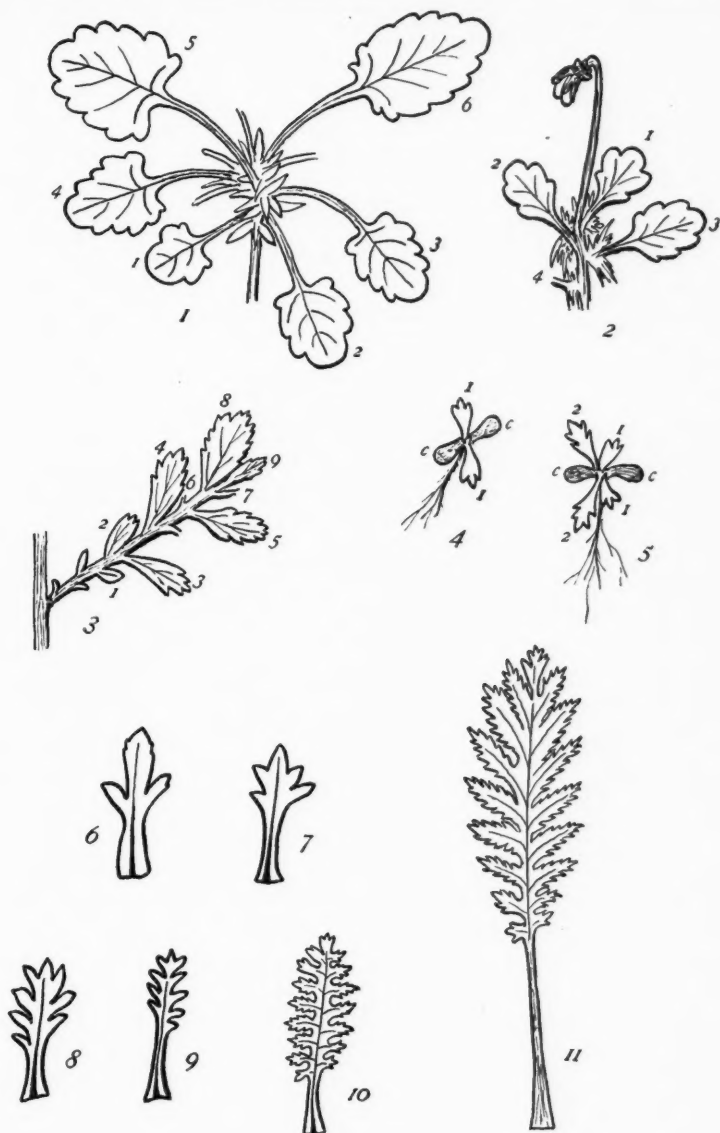
PLATE III.

PLATE IV.

(All natural size.)

Rosa rubiginosa L.

FIG. 1. Seedling showing cotyledons, and simple first and trifoliolate second nepionic leaves.

FIG. 2. Seedling with both first and second nepionic leaves trifoliolate.

Rosa lucida L.

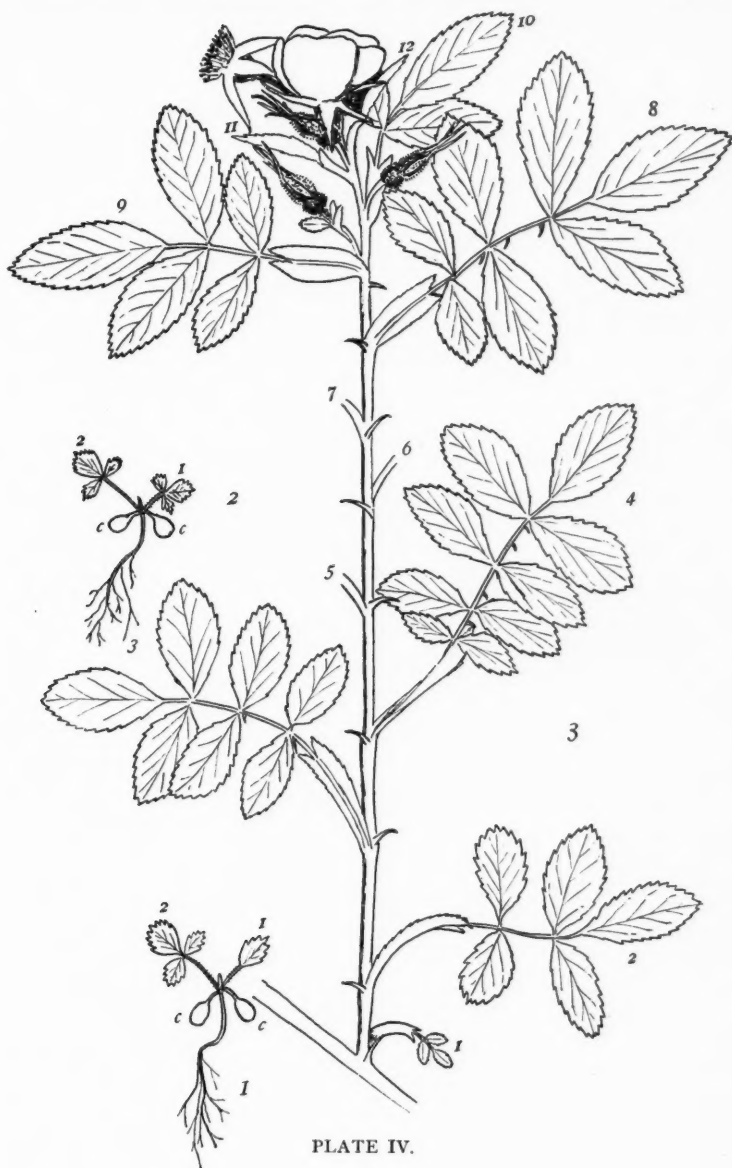FIG. 3. Stages from first leaf of spring growth, 1, to flowering stage, 12.

PLATE IV.

PLATE V.

Aquilegia canadensis L.

FIG. 1. Seedling with first nepionic leaf simple in outline, second normal. × 1.

FIG. 2. Seedling with normal form of first and second nepionic leaves. × 1.

FIG. 3. Stages in early spring growth from ground. Compare with seedlings and Fig. 4. × ½.

FIG. 4. Stages below flower, partly diagrammatic in apparent crowding, but each leaf in its relative position and shape. Numbered in reverse order for comparison with Fig. 3 and seedlings.
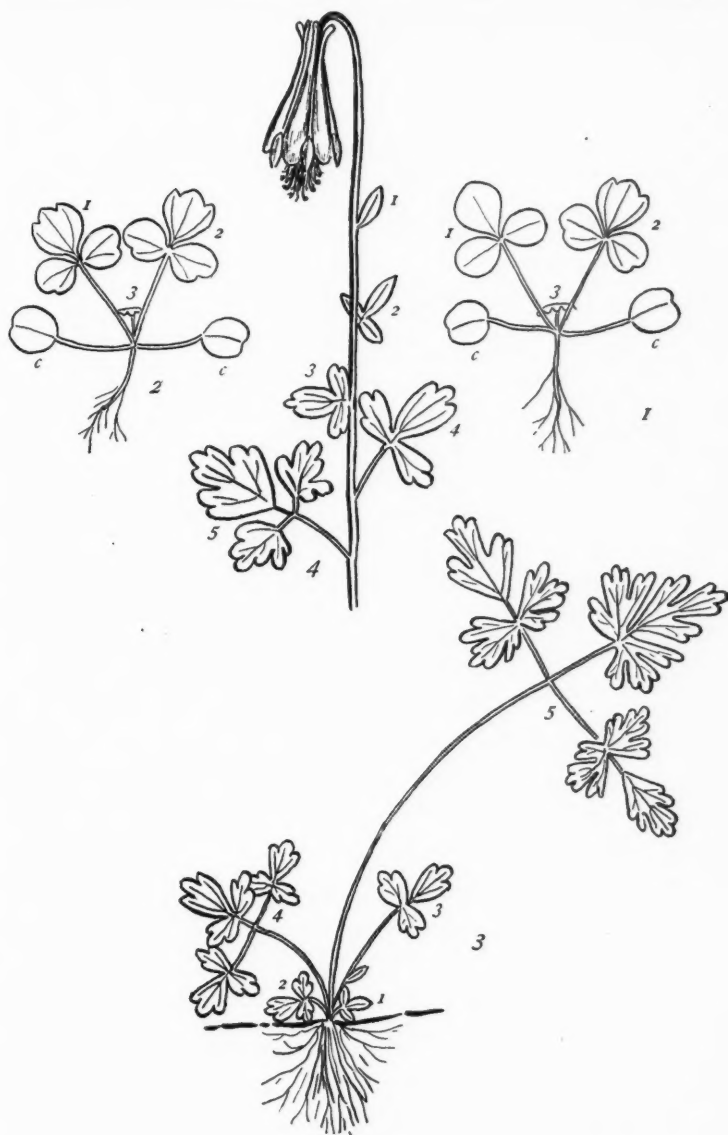
PLATE V.

SYNOPSES OF NORTH–AMERICAN INVERTEBRATES.

XII. THE TREMATODES.

PART II.[1] *— THE ASPIDOCOTYLEA AND THE MALA-COCOTYLEA, OR DIGENETIC FORMS.*

H. S. PRATT.

THE following are the families, subfamilies, and genera of the suborders Aspidocotylea and Malacocotylea, as arranged by Braun, Fischoeder, Looss, Lühe, Monticelli, Stiles and Hassall, and others :

Order. — Trematoda Rud.

Suborder II. Aspidocotylea Mont.

Family. Aspidobothridæ Burm.

Genera : Macraspis, Stichocotyle, Aspidocotylus, Platyaspis, Cotylaspis, Cotylogaster, Aspidogaster, Lophotaspis.

Suborder III. Malacocotylea Mont.

Family I. Paramphistomidæ Fisch.

Subfamily I. Paramphistominæ Fisch.

Genera : Gastrothylax, Paramphistomum, Stephanopharynx.

Subfamily II. Cladorchinæ Fisch.

Genera : Gastrodiscus, Homologaster, Diplodiscus, Cladorchis, Chiorchis. Related genus : Balanorchis.

Family II. Fasciolidæ Rail.

Subfamily I. Fasciolinæ S. et H.

Genera : Fasciola, Fasciolopsis, Campula. Related genera : Pleorchis, Paragonimus.

Subfamily II. Omphalometrinæ Lss.

Genera : Omphalometra, Cathæmasia.

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[1] Part I appeared in the *American Naturalist*, vol. xxxiv (August, 1900), p. 645. The figures illustrating Part II will appear in the continuation, in the December number of the *American Naturalist*.

Subfamily III. Opisthorchiinæ Lss.

Genera : Opisthorchis, Holometra, Metorchis.
Related genus : Podocotyle.

Subfamily IV. Telorchiinæ Lss.

Genera : Telorchis, Orchidasmus.
Related genus : Deropristis.

Subfamily V. Echinostominæ Lss.

Genera : Echinostoma, Stephanochasmus, Dihemistephanus, Stephano-
prora.
Related genus : Rhopalias.

Subfamily VI. Psilostominæ Pratt.

Genera : Psilostomum, Crepidastomum, Rhytidodes, Allocreadium, Caly-
codes, Azygia, Halicometra, Cotylotretus.
Related genera : Ptychogonimus, Orchipedum.

Subfamily VII. Anisocœlinæ Lss.

Genera : Anisocœlium, Anisogaster.

Subfamily VIII. Centrocestinæ Lss.

Genera : Centrocestus, Ascocotyle.
Related genera : Acanthochasmus, Anoiktastoma.

Subfamily IX. Cotylogoniminæ Pratt.

Genera : Cotylogonimus, Cryptocotyle.

Subfamily X. Philophthalminæ Lss.

Genera : Philophthalmus, Pygorchis.

Subfamily XI. Plagiorchiinæ Pratt.

Genera : Opisthioglyphe, Plagiorchis.
Related genera : Glossidium, Endiotrema, Pachypsolus.

Subfamily XII. Reniferinæ Pratt.

Genera : Styphlodora, Ochetosoma, Renifer, Oistosomum, Astiotrema.

Subfamily XIII. Bunoderinæ Pratt.

Genera : Bunodera, Tergestia.

Subfamily XIV. Haplometrinæ Pratt.

Genera : Haplometra, Hæmatolœchus, Ostiolum, Macrodera.
Related genera : Opisthogonimus, Asymphylodora.

Subfamily XV. Anaporrhutinæ Lss.

Genera : Anaporrhutum, Plesiorchorus.
Related genus : Callodistomum.

Subfamily XVI. Gorgoderinæ Lss.

Genera: Phyllodistomum, Gorgodera.

Subfamily XVII. Microphallinæ Ward.

Genera : Microphallus, Levinsenella.

Subfamily XVIII. Brachycœliinæ Lss.

Genera : Phaneropsolus, Lecithodendrium, Pycnoporus, Brachycœlium.
Related genera : Cymatocarpus, Brandesia.

Subfamily XIX. Pleurogenetinæ Lss.

Genera : Prosotocus, Pleurogenes, Gymnophallus, Lepidophyllum.

Subfamily XX. Cephalogoniminæ Lss.

Genera : Cephalogonimus, Emoleptalea, Prosthogonimus.
Related genus : Stromylotrema.

Subfamily XXI. Dicrocœliinæ Lss.

Genera : Dicrocœlium, Lyperosomum, Athesmia.
Related genera : Eumegacetes, Anchitrema.

Subfamily XXII. Hemiurinæ Lss.

Genera : Hemiurus, Lecithocladium, Pronopyge, Lecithochirium, Lecithas-
    ter, Liopyge, Derogenes.

Subfamily XXIII. Syncœliinæ Lss.

Genera : Progonus, Syncœlium, Otiotrema.
Related genus : Halipegus, Accacœlium, Eurycœlum.

Subfamily XXIV. Harmostominæ Lss.

Genera : Harmostomum, Ityogonimus, Glaphyrostomium, Scaphiostomum.

Subfamily XXV. Urogoniminæ Lss.

Genera : Urorygma, Urogonimus, Urotocus, Urotrema.

Subfamily XXVI. Zoögoninæ Odh.

Genera : Zoögonus, Zoögonoides.

Subfamily XXVII. Clinostominæ Pratt.

Genera : Clinostomum, Nephrocephalus.
Additional genera : Sperostoma, Microlistrum, Mesotretes, Hapalometra,
    Distomum.

Family III. Schistosomidæ Lss.

Genera : Schistosoma, Bilharziella, Kœllikeria.

Family IV. Holostomidæ Brds.

Subfamily I. Cyathocotylinæ Pratt.

Genus : Cyathocotyle.

Subfamily II. Diplostominæ Brds.

Genera: Diplostomum, Polycotyle.

Subfamily III. Hemistominæ Brds.

Genus: Hemistomum.

Subfamily IV. Holostominæ Brds.

Genus: Holostomum.

Family V. Gasterostomidæ Brn.

Genus: Gasterostomum.

Family VI. Didymozoönidæ Mont.

Genera: Didymozoön, Nematobothrium.

Family VII. Monostomidæ Mont.

Subfamily I. Microscaphidiinæ Lss.

Genera : Microscaphidium, Deuterobaris.

Subfamily II. Pronocephalinæ Lss.

Genera : Pronocephalus, Pleurogonius, Glyphicephalus, Adenogaster, Crico-
cephalus, Pyelosomum.
Related genus: Charaxicephalus.

Subfamily III. Haplorchidinæ Lss.

Genera : Haplorchis, Galactosomum.
Additional genera : Opisthotrema, Cyclocœlum, Notocotylus, Ogmogaster,
Stictodora, Mesometra, Monostomum.

ORDER. — TREMATODA RUD.

Small parasitic flatworms, with unsegmented, flattened or cylindrical,
unciliated bodies, with usually anterior mouth opening and bifurcate intes-
tine, and without anal opening, which attach themselves to their hosts by
means of suckers, or hooks, or both.

KEY TO THE SUBORDERS.

A_1. Usually ectoparasitic trematodes living upon the external surface or
the gills, or in the mouth or cloaca of aquatic animals (except genus
Polystoma), to which they attach themselves by means of suckers,
or hooks, or both ; suckers, when present, are usually near either
one or both ends of the body ; when at the anterior end, in most
cases, a single pair is present ; when at the posterior end, in most
cases, one or more pairs are present, or, in their place, a sucking
disk . . . . Heterocotylea Mont.

A_2. Endoparasitic trematodes which attach themselves to their hosts either
by means of one or more median (unpaired) suckers or a large
ventral sucking disk ; hooks never present.

B_1. Either a large ventral sucking disk or a mid-ventral row of suck-
ers present; no oral sucker; intestine not bifurcate (except
possibly Aspidocotylus) . . . . . . Aspidocotylea Mont.

B_2. Either one or two or, in a few cases, more than two median
suckers present; an oral sucker invariably present (except
Gasterostomum); intestine, except in rare cases, bifurcate
Malacocotylea Mont.

KEY TO THE GENERA OF THE SUBORDER ASPIDOCOTYLEA AND THE FAMILY ASPIDOBOTHRIDÆ.

a_1. A single mid-ventral row of suckers present, extending nearly or quite
the length of the body, which is elongate and cylindrical.

b_1. Suckers contiguous and confluent, on a distinct ridge of the body;
one testis: in gall bladder of Chimæra
Macraspis Olss. (Fig. 1) (55, 66)[1]

b_2. Suckers not contiguous and not on a ridge; two testes: in gall pas-
sages of skates (as adults) and in cysts in the end-intestine of
lobsters (as larvæ) . Stichocotyle Cunn. (Fig. 2) (62, 68, 66)

a_2. Very large circular or oval sucking disk present.

b_1. Sucking disk circular, containing a number of small round sucking
pits; intestine possibly bifurcate: in the intestine of fresh-water
fish . . . . Aspidocotylus Dies. (Fig. 3) (58, 66)

b_2. Sucking disk circular or elliptical and containing three or four lon-
gitudinal rows of more or less rectangular depressions separated
from one another by ridges.

c_1. Sucking disk with three rows of depressions.

d_1. Sucking disk irregularly circular or elliptical, with crenulate
border and with transversely elongated depressions; one
testis.

e_1. Number of depressions about twenty-five; marginal
sense organs and eyes absent: in intestine of cheloni-
ans . . . . Platyaspis Mont. (Fig. 4) (58, 66)

e_2. Number of depressions about twenty-nine; twenty
marginal sense organs and two eyes present: in
mantle chamber of fresh-water mussels
Cotylaspis Leidy (Fig. 5) (22, 17, 66)

d_2. Sucking disk elliptical, with very long transversely elongated
median depressions and small round lateral ones; two
testes; marginal sense organs: in the intestine of fish
Cotylogaster Mont. (Fig. 6) (58, 66)

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[1] The numbers in parentheses following the name of a genus or a species refer
to the publications in the bibliography in which detailed descriptions of it may be
found.

c_2. Sucking disk with four rows of depressions; one testis; marginal sense organs.

    d_1. Number of depressions seventy-seven; small protrusile tentacle-like sacks at the corners of the ridges : in the stomach of sea turtles . . . . **Lophotaspis** Lss. (49)

    d_2. Number of depressions 64–120; no protrusile sacs : in fresh-water mussels

                    Aspidogaster v. Baer (Fig. 7) (58, 66)

Key to the Families, Subfamilies, and Genera of the Suborder Malacocotylea.

a_3. But one sucker present (see p. 908).

a_2. Two suckers present, the oral sucker and the acetabulum, together with a large variously constructed ventral projection or disk of use in attachment (see p. 908).

a_1. Two suckers present, the oral sucker and the acetabulum, the latter either at the posterior end or in the mid-ventral surface; no other organ of attachment present.

  b_1. Acetabulum at posterior end, either terminal or subterminal

                    Family I. Paramphistomidæ

    c_1. Lateral pharyngeal pockets not present; cirrus sac absent

                  Subfamily I. Paramphistominæ

      d_1. Genital pore opens near oral sucker into a large pouch; acetabulum terminal; body cylindrical : in herbivores

                  Gastrothylax Poir. (Fig. 8) (11)

      d_2. Genital pouch not present; testes near center of body; ovary behind them : usually in herbivores.

        e_1. Pharynx with ring-shaped projection near its hinder end; intestine long and serpentine

                  Stephanopharynx Fisch. (11)

        e_2. Pharynx without ring-shaped projection; body conical; acetabulum subterminal

                Paramphistomum Fisch. (Fig. 9) (11)

    c_2. Lateral pharyngeal pockets present; cirrus sac present

                  Subfamily II. Cladorchinæ

      d_1. Ventral surface with numerous papillæ.

        e_1. Acetabulum minute and subterminal; body made up of two portions, a slender anterior portion and a very broad, disklike posterior portion, which contains numerous papillæ on its concave ventral surface : in intestines of herbivores   **Gastrodiscus** Leuck. (Fig. 10) (11)

        e_2. Acetabulum large and subterminal; entire ventral surface covered with papillæ : in intestine of mammals

                Homologaster Poir. (Fig. 11) (11)

d_2. No ventral papillæ present.

e_1. Testes simple, not lobate or dendritic.

f_1. Acetabulum terminal with excretory pore in its center; testes often fused to form a single body: in the rectum of amphibians

Diplodiscus Dies. (Fig. 12) (41)

f_2. Excretory pore not in acetabulum; testes in extreme hinder part of body with ovary in front of one of them; genital pore with a muscular fold around it; very small worms: in the stomach of herbivores . . . . . . Balanorchis Fisch. (11)

e_2. Testes dendritic, near center of body.

f_1. Intestine long and serpentine; no bulblike widening of œsophagus; ovary near acetabulum: in mammals . . . . . . Cladorchis Fisch. (11)

f_2. Intestine straight; œsophagus with bulblike widening; ovary behind testes, which lie one behind the other and are each cross shaped

Chiorchis Fisch. (11)

b_2. Acetabulum in the mid-ventral surface, but not at posterior end.

c_1. Worms hermaphroditic . . . . . Family II. Fasciolidæ

d_3. Ovary between testes (see p. 906).

d_2. Ovary behind testes (see p. 903).

d_1. Ovary in front of testes.

e_1. Uterus does not extend back of testes.

f_1. Intestinal cœca long and with lateral projections: yolk glands very voluminous: usually in the liver or lungs of mammals   Subfamily I. Fasciolinæ

g_1. Worms of large size, broad and leaf-like; acetabulum near anterior end; intestinal cœca, testes, and ovary profusely branched.

h_1. Body elongate; anterior end conical and more or less set off from remainder of worm . Fasciola L. (Fig. 13) (44, 83)

h_2. Body circular

Fasciolopsis Lss. (Fig. 14) (44)

g_2. Worms not of large size; lateral branches of intestinal cœca short and few.

h_1. Testes two, one behind the other: in liver of Cetacea

Campula Cob. (Fig. 15) (4, 86)

h_2. Testes numerous, in two longitudinal rows: intestinal cœca with but two branches, which pass anteriad: in fish

Pleorchis Rail. (Fig. 16) (86)

f_2. Intestinal cœca without lateral projections.

    g_1. Genital pore immediately behind acetabulum (but not on a papilla) ; body thick and egg-shaped ; intestinal cœca long; testes lobate, in same transverse plane ; yolk glands very large ; uterus very small, near acetabulum : in lungs of mammals

                                    Paragonimus Brn. (Fig. 17) (87)

    g_2. Genital pore in front or at left side of acetabulum or, if behind, on a papilla.

        h_1. Yolk glands dendritic, *i.e.*, diffuse and not compact.

            i_1. Either a ring of spines or two spiny, retractile tentacles at anterior end.

                j_1. Testes in same transverse plane behind acetabulum ; mouth surrounded by spines.

                    k_1. Testes and yolk glands near middle of body, which is broad   Anoiktastoma Stoss. (Fig. 18) (44)

                    k_2. Testes and ovary at extreme hinder end of body : in small intestine of birds and mammals

                            Subfamily VIII. Centrocestinæ

                      l_1. Intestinal cœca long ; œsophagus wanting ; testes and yolk gland large

                          Centrocestus Lss. (Fig. 19) (44)

                      l_2. Intestinal cœca short, not reaching acetabulum ; œsophagus long ; a dorsal lip over mouth ; oral sucker prolonged posteriorly into a long, blind sac   Ascocotyle Lss. (Fig. 20) (44)

                j_2. Testes one behind the other, not in same transverse plane.

                    k_1. Two spiny, retractile tentacles present, one on either side of mouth : in the opossum

                        Rhopalias S. et H. (Fig. 21) (86, 7)

                    k_2. Tentacles not present ; body usually elongate and cylindrical ; mouth surrounded by spines.

                      l_1. Testes and ovary close together in extreme hinder end of body ; oral sucker large and surrounded by a single row of spines: in reptiles and fish

                        Acanthochasmus Lss. (Fig. 22) (44, 48)

                    l_2. Testes and ovary usually not all close together and not in extreme hinder part of body, although in posterior half.

                        m_1. Intestinal cœca do not reach to end of body and not of equal length ; testes elongate ; mouth surrounded by a single row of spines : in intestine of fish

                        Subfamily VII. Anisocœlinæ

n_1. Testes very small and elongate and in center of body; ovary lobate; uterus does not extend to end of intestinal cœca

Anisocœlium Lühe (Fig. 23) (52)

n_2. Testes elliptical, in hinder half of body; ovary spherical : uterus extends to end of body

Anisogaster Lss. (Fig. 24) (49)

m_2. Intestinal cœca extend to end of body, or nearly so, and are of equal length   Subfamily V. Echinostominæ

n_1. Mouth surrounded by a single row of spines.

o_1. Oral spines set in a more or less reniform ridge and interrupted mid-ventrally

Echinostoma R. (Fig. 25) (44)

o_2. Oral spines not set in a ridge or interrupted ventrally; a number of unusually large spines just back of mouth : in crocodiles

Stephanoprora Odh. (71)

n_2. Mouth surrounded by a double row of spines.

o_1. Spines entirely surround mouth; long pre-pharynx present : in fish

Stephanochasmus Lss. (Fig. 26) (44, 48)

o_2. No spines on ventral side of mouth, but a little back of this is a group of short spines

Dihemistephanus Lss. (Fig. 27) (48)

i_2. Neither a ring of spines nor tentacles present at anterior end.

j_1. Testes two in number, one behind the other, often obliquely, but never in same transverse plane; body usually elongate.

k_1. Ovary separated from one or both testes by half the length of the body, the space being filled by the uterus; cirrus sac very long : in turtles .   .   .   . Subfamily IV. Telorchiinæ

l_1. Both testes at extreme hinder end of body

Telorchis Lühe (Fig. 28) (50, 10)

l_2. One testis at extreme hinder end and one near ovary

Orchidasmus Lss. (Fig. 29) (44, 45)

k_2. Ovary not widely separated from testes; uterus usually in front of ovary.

l_1. Excretory vesicle Y-shaped, with very long stem, which winds between the testes; receptaculum seminis large; no cirrus sac : in the liver of mammals, birds, and reptiles

Subfamily III. Opisthorchiinæ

m_1. Yolk glands do not extend forward of acetabulum; uterus confined between intestinal cœca

Opisthorchis R. Bl. (Fig. 30) (44)

m_2. Yolk glands partly or wholly in front of acetabulum; uterus usually overlapping intestinal cœca.

n_1. Yolk glands entirely in front of acetabulum;
uterus extends back of ovary to testes

Holometra Lss. (Fig. 31) (44)

n_2. Yolk glands partly behind acetabulum

Metorchis Lss. (Fig. 32) (44)

l_2. Stem of excretory vesicle usually entirely posterior to testes;
cirrus sac present.

m_1. Testes lobate: prepharynx present

Subfamily II. Omphalometrinæ

n_1. Œsophagus absent; intestinal cœca do not extend
into extremity of body; yolk glands meet in
median line: in Ciconia

Omphalometra Lss. (Fig. 33) (44)

n_2. Œsophagus present.

o_1. Acetabulum pedunculate; ovary lobate; ute-
rus extends in zigzags to genital pore; yolk
glands meet in median line

Podocotyle Stoss. (51)

o_2. Ovary spherical; acetabulum sessile; uterus
massed between them; yolk glands laterad of
intestinal cœca

Cathæmasia Lss. (Fig. 34) (44)

m_2. Testes not lobate.

n_1. Yolk glands extend in front of acetabulum.

o_1. Anterior end with projecting ridges or with six
papillæ.

p_1. Body subcylindrical; anterior end with
four projecting, radial ridges: in turtles

Calycodes Lss. (Fig. 35) (49)

p_2. Anterior end with six papillæ, two being
ventral and four dorsal: in fish

Crepidastomum Brn. (8)

o_2. Anterior end without ridges or papillæ; body
broad and flat.

p_1. Yolk glands very extensive, overlapping
intestinal cœca; ovary near testes and
not near acetabulum: in fish

Halicometra Odh. (Fig. 104) (70)

p_2. Yolk glands not overlapping intestinal
cœca: in amphibians

Opisthioglyphe Lss. (Fig. 47) (44)

n_2. Yolk glands do not extend in front of acetabulum

Subfamily VI. Psilostominæ

o_1. A pair of earlike papillæ present near mouth;
body elongate.

p_1. Acetabulum small; testes ovoid: in turtles
Rhytidodes Lss. (Fig. 36) (49)

p_2. Acetabulum very large; testes reniform:
in *Spilotes pullatus*, a Brazilian snake
Cotylotretus Odh. (Fig. 130) (71)

o_2. Anterior papillæ absent.

p_1. Anterior portion of body covered with
large spines and often inflated; remainder
of body with small spines: in fish
Deropristis Odh. (Fig. 105) (70)

p_2. No large anterior spines.

q_1. Œsophagus long; uterus short; recep-
taculum seminis and testes large: in
fish
Allocreadium Lss. (Fig. 37) (44, 45)

q_2. Œsophagus very short or wanting;
receptaculum seminis absent or
small.

r_1. Yolk glands extend back of
testes.

s_1. Large suckerlike genital pa-
pilla present in front of
acetabulum; uterus extends
to end of body
Ptychogonimus Lühe (Fig. 38) (51)

s_2. No genital papilla present;
uterus short, in front of
testes; prepharynx present;
in birds and fish
Psilostomum Lss. (Fig. 39) (44)

r_2. Yolk glands do not extend back
of testes; ovary far from ace-
tabulum, the space between
filled by the uterus; body elon-
gate: in fish
Azygia Lss. (Fig. 40) (44)

j_2. Testes either two in number, in same transverse plane in hinder end
of body, or many in number.

k_1. Testes numerous, in median field of body; no pharynx present;
ovary just back of acetabulum: in ducks
Orchipedum Brn. (9)

k_2. Testes two in number, in same transverse plane
Subfamily IX. Cotylogoniminæ

l_1. Genital pore in acetabulum; yolk glands very voluminous:
in birds .   .   .   Cryptocotyle Lühe (Fig. 41) (50, 10)

l_2. Genital pore on a muscular suckerlike
   papilla at posterio-lateral side of acetab-
   ulum; œsophagus long; yolk glands
   small : in mammals
      Cotylogonimus Lühe (Fig. 42) (50, 10)

h_2. Yolk glands compact, and lobate or tubular; worms oval
   or elliptical in shape; suckers large and often projecting;
   testes in extreme hinder end of body; cirrus sac long :
   in birds . . . . . Subfamily X. Philophthalminæ

   i_1. Cirrus sac extends back of acetabulum; yolk glands
      tubular, laterad of intestinal cœca : under the eyelid
      of birds . . Philophthalmus Lss. (Fig. 43) (44)

   i_2. Cirrus sac does not extend back of acetabulum ; yolk
      glands lobate, not laterad of intestinal cœca : in
      cloaca of birds . . Pygorchis Lss. (Fig. 44) (44)

e_2. Uterus extends back of testes, usually to end of body.

  f_1. Intestinal cœca long, extending more than half the length of body.

    g_1. Ovary immediately behind or at side of acetabulum, or when
      not near it the intestinal cœca do not extend into hinder
      extremity of body.

      h_1. Genital pore near the acetabulum or somewhere in front
        of it, but not at the extreme anterior or posterior end of
        body.

        i_1. Mouth surrounded by papilla-like or long spinelike pro-
          jections . . . . Subfamily XII. Bunoderinæ

          j_1. Mouth surrounded by six contractile projections;
            no spines present; uterus consists of a descend-
            ing and an ascending branch, without spinal
            windings : in fish
                Bunodera Rail. (Fig. 45) (44, 86)

          j_2. Mouth surrounded by long spinelike projections;
            uterus winds spirally : in Belone
                Tergestia Stoss. (Fig. 46) (44)

        i_2. No projections surrounding mouth.

          j_1. Intestinal cœca usually do not reach the end of
            the body (longest in Opisthioglyphe); body usu-
            ally spiny; excretory canal usually Y-shaped;
            cirrus sac present
               Subfamily XI. Plagiorchiinæ

           k_1. Uterus does not extend back of testes; œsoph-
             agus long; ovary at side of acetabulum : in
             amphibians
               Opisthioglyphe Lss. (Fig. 47) (44)

           k_2. Uterus extends back of testes.

            l_1. Œsophagus wanting.

m_1. Yolk glands extend forward of the acetabulum.

n_1. Testes not in same transverse plane; cirrus sac extends back of acetabulum : in amphibians, reptiles, and birds   Plagiorchis Lühe (Fig. 48) (50, 10)

n_2. Testes in same transverse plane.

o_1. Cirrus sac extends far back of acetabulum : in turtles   Pachypsolus Lss. (Fig. 49) (49)

o_2. Cirrus sac extends to middle of acetabulum ; body divided into two parts : in crocodiles   Oistosomum Oldh. (71)

m_2. Yolk glands do not extend in front of acetabulum; body elongate, tapering to posterior end, which is truncated : in fish   Glossidium Lss. (Fig. 50) (44)

l_2. Œsophagus present.

m_1. Body covered with minute spines or scales.

n_1. Testes not in same transverse plane.

o_1. One intestinal cœcum much longer than the other; testes elongate; a single row of spines around mouth : in fish

Subfamily VII. Anisocœlinæ

p_1. Testes very small, in center of body ; ovary lobate ; uterus does not extend to end of intestinal cœca

Anisocœlium Lühe (Fig. 23) (52)

p_2. Testes in hinder half of body ; ovary spherical ; uterus extends to end of body

Anisogaster Lss. (Fig. 24) (48)

o_2. Intestinal cœca of equal length.

p_1. Oral sucker larger than acetabulum ; yolk glands extend in front of latter ; stem of excretory vesicle very long, winding between testes ; receptaculum seminis minute ; cirrus sac long : in aquatic vertebrates

Astiotrema Lss. (Fig. 51) (44, 45)

p_2. Oral sucker smaller than acetabulum ; yolk glands do not extend in front of latter ; testes lobate ; receptaculum seminis large ; stem of excretory vesicle short : in reptiles

Styphlodora Lss. (Fig. 52) (44, 77)

n_2. Testes in nearly or quite the same transverse plane and lobate ; oral sucker smaller than acetabulum ; yolk glands extend about to acetabulum ; receptaculum seminis absent or minute ; stem of excretory vesicle very long : in reptiles

Renifer Pratt (Fig. 53) (77)

m_2. Body not spiny; cirrus sac very wide in front of acetabulum; yolk glands composed of a single row of follicles on each side: in turtles

Endiotrema Lss. (Fig. 54) (44, 45)

j_2. Intestinal cœca reach into extremity of body; testes usually in oblique plane or one behind the other.

k_1. Large suckerlike genital papilla present in front of acetabulum; suckers large; excretory crura join at anterior end

Ptychogonimus Lühe (Fig. 38) (51)

k_2. No genital papilla present   .   Subfamily XIV. Haplometrinæ

l_1. Genital pore just behind pharynx; cirrus sac very long and narrow.

m_1. Acetabulum larger than and near oral sucker; body elongate; testes and ovary in forward half of body; receptaculum seminis wanting or minute

Macrodera Lss. (44)

m_2. Acetabulum smaller than oral sucker and not near it; uterus very long and deeply colored; receptaculum seminis very large; Laurer's canal wanting; œsophagus wanting or short.

n_1. Uterus in long longitudinal folds; ovary beside acetabulum: in lungs of amphibians

Hæmatolœchus Lss. (Fig. 55) (44)

n_2. Uterus in transverse folds; ovary behind acetabulum, which is minute; testes very large: in frogs

Ostiolum Pratt (Fig. 56) (77)

l_2. Genital pore near acetabulum.

m_1. Genital pore just in front of acetabulum.

n_1. Œsophagus present.

o_1. Pharynx present.

p_1. Yolk glands extensive and dendritic; body elongate: in amphibians

Haplometra Lss. (Fig. 57) (44)

p_2. Yolk glands small, on each side of acetabulum; testes in same transverse plane just behind them; ovary to right of and just behind acetabulum; body broad: in fish

Callodistomum Odh. (70)

o_2. Pharynx absent; body broad; yolk glands very small lobate bodies just behind acetabulum

Phyllodistomum Brn. (Fig. 63) (8)

n_2. Œsophagus absent; body very broad; testes a large number of small round bodies

Anaporrhutum Ofen. (Fig. 64) (67)

m_2. Genital pore behind and to left of acetabulum;
cirrus sac U-shaped : in snakes
Opisthogonimus Lühe (Fig. 58) (50, 10)

h_2. Genital pore at the extreme anterior or posterior end of the body.

i_1. Genital pore in front of or at side of oral sucker .
Subfamily XX. Cephalogonimina

j_1. Testes one behind the other ; cirrus sac very long.

k_1. Excretory vesicle large, with long stem and crura, both
of which throw out side branches ; genital pore in
front of oral sucker
Cephalogonimus Poir. (Fig. 59) (44)

k_2. Excretory vesicle with long stem, short crura, and
without side branches ; genital pore at right of oral
sucker : in fish Emoleptalea Lss. (Fig. 60) (44, 45)

j_2. Testes in nearly same transverse plane and lobate ; genital
pore at left of oral sucker ; ovary lobate : in birds
Prosthogonimus Lühe (Fig. 61) (50, 10)

i_2. Genital pore at extreme hinder end of body; testes and ovary
in median line, the latter just behind acetabulum, the former
just in front of cirrus sac with the uterus between : in bats
Urotrema Brn. (9)

g_2. Ovary not immediately behind or at side of acetabulum; intestinal
cœca extend to end of body.

h_1. Genital pore in front of acetabulum and median ; yolk glands
small, being spherical, lobate, or dendritic bodies near the middle
of the body.

i_1. Yolk glands spherical ; excretory crura join near the pharynx :
acetabulum large   .   .   .   .   Liopyge Lss. (Fig. 88) (44)

i_2. Yolk glands lobate or dendritic.

j_1. Pharynx absent ; yolk glands small and lobate : in urinary
bladder of cold-blooded vertebrates
Subfamily XVI. Gorgoderina

k_1. Body elongate; either one pair of testes or four testes
on one side and five on the other
Gorgodera Lss. (Fig. 62) (44)

k_2. Body broad and leaflike; one pair of testes
Phyllodistomum Brn. (Fig. 63) (8)

j_2. Pharynx present ; body broad and leaflike; testes either nu-
merous or two in number Subfamily XV. Anaporrhutina

k_1. Testes made up of a large number of small bodies ; yolk
glands small and dendritic ; uterus not laterad of
intestinal cœca Anaporrhutum Ofen. (Fig. 64) (67)

k_2. Testes two large, lobate bodies ; yolk glands lobate ;
uterus extends laterad of intestinal cœca : in turtles
Plesiorchorus Lss. (Fig. 65) (46)

h_2. Genital pore on edge of body.

i_1. Genital pore on right edge of body opposite pharynx; suckers very large; testes in same transverse plane in front of acetabulum : in birds
Stromylotrema Lss. (Fig. 66) (44, 45)

i_2. Genital pore on left edge of body opposite acetabulum; but one testis present : in fish
Asymphylodora Lss. (Fig. 67) (44)

f_2. Intestinal cœca very short, extending but little, if any, beyond the acetabulum, and often not to it; excretory vesicle usually wide, long, and V- or Y-shaped; testes usually in same transverse plane.

g_1. Intestinal cœca reach about to acetabulum or a little beyond, and are usually longer than the œsophagus; yolk glands small . . . . . . Subfamily XIX. Pleurogenetinæ

h_1. Genital pore at left side of body near forward end; cirrus sac large.

i_1. Testes small, lobate, just behind yolk glands and ovary, all being behind acetabulum : in fish
Lepidophyllum Odh. (Fig. 106) (70)

i_2. Yolk glands and ovary in front of testes : in amphibians and reptiles.

j_1. Testes one on each side of acetabulum; œsophagus long; body elliptical
Pleurogenes Lss. (Fig. 68) (43, 44)

j_2. Testes far in front of acetabulum and ovary; body oval or round; œsophagus short
Prosotocus Lss. (Fig. 69) (44)

h_2. Genital pore in or very near acetabulum.

i_1. Genital pore in anterior border of acetabulum; excretory vesicle Y-shaped and very long
Gymnophallus Odhner (Fig. 70) (69)

i_2. Genital pore not in acetabulum.

j_1. Genital pore at left side of acetabulum; yolk glands behind testes
Levinsenella S. et H. (Fig. 71) (44, 15)

j_2. Genital pore in front of acetabulum; yolk glands in front of testes : in Corone
Ochetosoma Brn. (9)

g_2. Intestinal cœca very short, usually falling short of acetabulum; ovary usually near acetabulum; yolk glands small; testes usually in same transverse plane
Subfamily XVII. Brachycœliinæ

h_1. Body elongate and spiny.

i_1. Acetabulum small, about size of oral sucker ; cirrus
 sac large and extending back of acetabulum;
 yolk glands dendritic, extending in front of ace-
 tabulum : in turtles
       Cymatocarpus Lss. (Fig. 72) (44)

i_2. Acetabulum very large ; cirrus sac small, in front
 of acetabulum; yolk glands lobate, behind
 acetabulum : in amphibians and reptiles
      Brachycœlium Duj. (Fig. 73) (44)

h_2. Body short, oval, usually spiny.

 i_1. Testes behind and ovary to right of acetabulum.

  j_1. Genital pore median, in front of acetabulum ;
   yolk glands, one on each side of acetabu-
   lum : in bats
       Pycnoporus Lss. (Fig. 74) (44)

  j_2. Genital pore at left side of acetabulum
      Subfamily XVII. Microphallinæ

   k_1. Yolk glands lobate, in hinder part of body ;
    vesicula seminalis large, in front of
    acetabulum ; no spines: in fresh-water fish
    Microphallus Ward (Fig. 75) (92, 94)

   k_2. Intestinal cœca reach a little beyond ace-
    tabulum; spines present
    Levinsenella S. et H. (Fig. 71) (44, 15)

 i_2. Testes in front of or on each side of acetab-
  ulum.

  j_1. Genital pore median, between oral sucker and
   acetabulum; testes one on each side of and
   ovary to left of acetabulum.

   k_1. Genital pore near acetabulum; œsophagus
    long; yolk glands behind acetabulum;
    no cirrus sac : in bats and chameleons
    Lecithodendrum Lss. (Fig. 76) (44)

   k_2. Genital pore near pharynx; œsophagus
    short ; yolk glands far in front of acetab-
    ulum; long cirrus sac present: in birds
    and mammals
    Phaneropsolus Lss. (Fig. 77) (44)

  j_2. Genital pore at left side of body ; acetabulum
   in hinder part of body ; all the genital glands
   in front of them ; œsophagus short : in frogs
    Brandesia Stoss. (Fig. 78) (44)

d_2. Ovary behind testes.

 e_1. Testes in front of acetabulum, in same transverse plane.

f_1. Ovary behind acetabulum; suckers large; genital pore near pharynx; no œsophagus present: in cloaca of birds

Eumegacetes Lss. (Fig. 79) (44, 45)

f_2. Ovary in front of acetabulum; suckers not large.

   g_1. Genital pore at extreme hinder end: in birds

Urorygma Brn. (9)

   g_2. Genital pore in front of acetabulum; intestinal cœca not reaching acetabulum.

   h_1. Genital pore median.

   i_1. Cirrus sac long; yolk glands in front of acetabulum: in birds and mammals

Phaneropsolus Lss. (Fig. 77) (44)

   i_2. No cirrus sac; yolk glands behind acetabulum: in bats and chameleons

Lecithodendrium Lss. (Fig. 76) (44)

   h_2. Genital pore on left edge of body; cirrus sac long; genital glands all in front of acetabulum: in amphibians and reptiles

Prosotocus Lss. (Fig. 69) (44)

e_2. Testes behind acetabulum.

   f_1. Yolk glands dendritic and along the sides of the body.

   g_1. Testes one behind the other; body elongate; intestinal cœca extending to end of body.

   h_1. Yolk glands consist of a series of branched tubular follicles on each side.

   i_1. Œsophagus very long; each intestinal cœcum sends a long projection forward, giving the digestive tract the form of an H; acetabulum often pedunculate: in fish

Accacœlium Mont. (Fig. 80) (44, 59)

   i_2. Acetabulum not pedunculate; digestive tract not in form of an H; acetabulum in middle of body, the anterior half of which is flat, the posterior half cylindrical

Eurycœlum Brock. (55)

   h_2. Yolk glands not of tubular follicles, but of spheroidal masses; œsophagus short; suckers near together: usually in the liver   Subfamily XXI. Dicrocœliinæ

   i_1. But one yolk gland, the left one, present: in liver of birds   .   .   .   Athesmia Lss. (Fig. 81) (44)

   i_2. A pair of yolk glands present.

   j_1. Body flat and leaf-like

Dicrocœlium Duj. (Fig. 82) (44, 86)

   j_2. Body cylindrical

Lyperosomum Lss. (Fig. 83) (44)

g_2. Testes in same transverse plane or nearly so; intestinal cœca extend to end of body; excretory canal Y-shaped; cirrus sac wanting: in bats and chameleons

Anchitrema Lss. (44)

f_2. Yolk glands compact, or if dendritic, of small extent and not along the sides of the body.

g_1. Genital pore in front of acetabulum.

h_1. Yolk glands in hinder end of body.

i_1. Distal ends of intestinal cœca joined; distal ends of excretory crura also joined: in marine fish

Subfamily XXIII. Syncœliinæ

j_1. Yolk glands compact, spherical; testes in same transverse plane: in the stomach

Progonus Lss. (Fig. 84) (44)

j_2. Yolk glands dendritic: on gills of sharks.

k_1. Intestinal cœca have side branches; testes and ovary dentritic; acetabulum pedunculate; anterior portion of body cylindrical, posterior flat and folded

Otiotrema Setti (Fig. 85) (44)

k_2. Intestinal cœca without side branches; ovary deeply lobate; testes in two longitudinal rows of isolated lobes

Syncœlium Lss. (Fig. 86) (44)

i_2. Distal ends of intestinal cœca not joined; testes usually in same transverse plane in hinder end of body; uterus in transverse folds, passing to anterior end of body: in amphibians

Halipegus Lss. (Fig. 87) (44)

h_2. Yolk glands near or towards the middle of the body (except Derogenes); excretory crura usually joining over the pharynx; small cylindrical or elliptical forms, in most of which the hinder end of the body is telescopic: in marine fish

Subfamily XXII. Hemiurinæ

i_1. Hinder end of body not telescopic (no appendix); genital pore near branching of intestine.

j_1. Testes behind ovary and diagonally behind each other; yolk glands in front of ovary; all genital glands spherical

Liopyge Lss. (Fig. 88) (44)

j_2. Testes in front of ovary, in nearly same transverse plane; yolk glands lobate and behind ovary

Derogenes Lühe (Fig. 89) (52, 55)

i_2. Hinder end of body telescopic (with appendix).

j_1. Body elongate, finely ringed.

k_1. Yolk glands spherical, behind ovary; appendix either long, medium, or short; receptaculum seminis large

Hemiurus R. (Fig. 90) (44, 55, 57, 76)

k_2. Yolk glands composed of three or four long, involved tubes on each side; appendix long

Lecithocladium Lühe (Fig. 91) (55)

j_2. Body fusiform or ovate; not ringed.

k_1. Yolk glands spherical, near acetabulum; excretory crura do not join anteriorly; testes in same transverse plane; appendix very short

Pronopyge Lss. (Fig. 92) (44)

k_2. Yolk glands deeply lobate or tubular, behind testes.

l_1. Yolk glands apparently joined to form a single star-shaped body

Lecithaster Lühe (Fig. 93) (55)

l_2. Yolk glands distinctly separate from each other, and each composed of three or four tubular lobes

Lecithochirium Lühe (Fig. 94) (55)

g_2. Genital pore on left edge of body nearly opposite acetabulum; but one yolk gland present, a small ovoid structure in center of the body; testes in same transverse plane: in fish . . . . . . Subfamily XXVI. Zoögoninæ

h_1. Testes just back of acetabulum; yolk gland just in front of ovary . . Zoögonus Lss. (Fig. 95) (47)

h_2. Testes one on each side of acetabulum; yolk gland just behind ovary

Zoögonoides Odh. (Fig. 96) (70)

d_3. Ovary between the testes, which are often one behind the other.

e_1. Genital pore in front of acetabulum; suckers large; œsophagus and intestinal cœca long; testes and cirrus sac large; yolk glands extensive, along entire sides of body: in fish

Spærostoma R. (Fig. 97) (44, 86)

e_2. Genital pore behind acetabulum.

f_1. Genital pore at hinder extremity of body; œsophagus absent; yolk glands voluminous: in birds and bats

Subfamily XXV. Urogoniminæ

g_1. Suckers very large; testes obliquely behind each other; body broad . . . Urogonimus Mont. (Fig. 98) (44)

g_2. Suckers not large ; testes directly behind one another ;
    body elongate . .   Urotocus Lss. (Fig. 99) (44)

f_2. Genital pore not at hinder extremity of body but usually
    near testes.

g_1. Genital pore between testes, which are very large and
    broken up into a large number of distinct parts; no
    pharynx, a long œsophagus, and long intestinal cœca
    present : in sea turtles

Hapalotrema Lss. (Fig. 100) (44)

g_2. Testes not broken into small parts.

h_1. Mouth surrounded by circular ridge; intestine
    usually with short lateral projections

Subfamily XXVII. Clinostominæ

i_1. Genital pore just in front of testes ; pharynx
    absent : in mouth of birds

Clinostomum Leidy (Fig. 101) (21, 6)

i_2. Genital pore a short distance in front of pos-
    terior end; pharynx present: in crocodiles

Nephrocephalus Odh. (71)

h_2. Mouth not surrounded by ridge

Subfamily XXIV. Harmostominæ

i_1. Genital pore in front of anterior testis.

j_1. Body linguiform ; mouth a slit; ovary and
    testes in extreme hinder end : in mammals

Harmostomum Brn. (Fig. 102) (10)

j_2. Body very elongate and cylindrical ; genital
    glands not in extreme hinder end : in
    birds . . .   Scaphistomum Brn. (9)

i_2. Genital pore between the testes.

j_1. Body very elongate, tapelike ; acetabulum
    very small ; oral sucker large ; genital
    pore near forward end of hinder testis ;
    testes far apart : in Talpa

Ityogonimus Lühe (Fig. 103) (50, 10)

j_2. Body elongate, linguiform ; genital pore just
    behind anterior testis ; mouth circular: in
    Mycotheria from Brazil

Glaphyrostomum Brn. (9)

c_2. Worms diœcious . . . . Family III. Schistosomidæ

d_1. Hinder portion of body expanded in both sexes ; female shorter than
    male : in the blood and liver of birds .   Bilharziella Lss. (44)

d_2. Body cylindrical in both sexes or expanded in female.

e_1. Female longer than male and filiform, and enclosed in the
    gynæcophoric canal of the latter : in the blood of mammals

Schistosoma Wein. (Fig. 107) (44)

e_2. Male and anterior portion of female filiform; posterior portion of female swollen and reniform: in the mouth and gill clefts of fish, living in cysts, a male and a female being in a cyst   .   Kœllikeria Cob. (Fig. 108) (86)

a_2. Two suckers present, the oral sucker and the ventral acetabulum, together with a large, variously constructed ventral projection, or disk, of use in attachment   .   .   .   .   .   .   Family IV. Holostomidæ

b_1. Body circular, not made up of two portions; acetabulum usually covered by a large disklike structure which possesses a large cavity extending itself into a longitudinal groove: in intestine of birds   .   .   .   .   Cyathocotyle Mühl. (Fig. 109) (60)

b_2. Body elongate and made up of two distinct portions, the anterior portion being usually flattened and containing the acetabulum and the special organ of attachment.

c_1. Lateral edges of anterior portion not bent ventrally; special organ of attachment an elongated depression lined with papillæ   .   .   .   .   Subfamily II. Diplostominæ

d_1. A row of mid-dorsal suckers on hinder part of body: in intestine of the alligator

Polycotyle Will.-S. (Fig. 110) (95)

d_2. No dorsal suckers: in intestine of reptiles and birds

Diplostomum v. Nord. (Fig. 111) (3)

c_2. Lateral edges of anterior portion bent ventrally.

d_1. Anterior portion trough-shaped; special organ of attachment an elongated elevation, which may project over the acetabulum.

e_1. In birds and land mammals

Hemistomum Dies. (Fig. 112) (3)

e_2. In Delphinus   .   .   .   .   .   .   Braunina Heider (12)

d_2. Lateral edges of anterior portion meet and fuse mid-ventrally, making this part of the body cup-shaped; special organ of attachment a conical projection: usually in birds   .   .   .   .   .   Holostomum Nit. (Fig. 113) (3)

a_3. But one sucker present and no other organ of attachment.

b_1. Mouth in the middle of the ventral body surface; sucker at anterior end; intestine not bifurcate; genital and excretory pores at posterior end: in the intestine of fish

Gasterostomum v. Sieb. (Fig. 114) (33)

b_2. Mouth at anterior end, sucker oral.

c_1. Worms found in pairs in cysts on the gills, outer surface, or in the mouth of fish; intestine often rudimentary or wanting

Family VI. Didymozoönidæ

d_1. Anterior portion of body slender and cylindrical, posterior portion thick and cylindrical, or reniform

Didymozoön Tasch. (Fig. 115) (3)

d_2. Body very elongate (up to a meter in length) and filiform ; intestine
        wanting but mouth present   . .   Nematobothrium v. Ben. (3)
c_2. Worms not found in pairs enclosed in cysts   Family VII. Monostomidæ
    d_1. Testes directly behind one another in middle of body ; ovary behind
            them ; body usually elongate, anterior end not set off ; genital
            pore near anterior end ; cirrus sac wanting ; uterus not volumi-
            nous ; intestinal cœca do not extend to end of body : in intestine
            of reptiles . . . .   Subfamily I. Microscaphidiinæ
        e_1. Uterus confined between intestinal cœca
                                Microscaphidium Lss. (Fig. 116) (44, 45)
        e_2. Uterus overlaps intestinal cœca
                                Deuterobaris Lss. (Fig. 117) (44, 45)
    d_2. Testes either in same transverse plane or obliquely behind one
            another ; ovary usually in front of testes or between them.
        e_1. Genital pore at hinder end of body, which is broad ; pharynx
                wanting : in Halicore   Opisthotrema Leuck. (Fig. 118) (3)
        e_2. Genital pore in anterior half of body.
            f_1. Intestinal cœca join at their hinder ends ; testes obliquely
                    behind one another : in water birds
                                    Cyclocœlum Brds. (Fig. 119) (44)
            f_2. Intestinal cœca not thus joined.
                g_1. Anterior end more or less triangular, being set off by a
                        circular muscular ridge from rest of body ; testes and
                        ovary often lobate in hinder end of body : in marine
                        turtles . . . . .   Subfamily II. Pronocephalinæ
                    h_1. Anterior ridge with a deep indentation on the
                            ventral side.
                        i_1. Ovary in front of testes, of which two are
                                present.
                            j_1. Intestinal cœca without side projections and
                                    with their posterior ends laterad of the
                                    testes ; latter not in same transverse plane
                                    Pronocephalus Lss. (Fig. 120) (44)
                            j_2. Intestinal cœca with side projections and
                                    with their posterior ends mediad of testes,
                                    which are in same transverse plane.
                                k_1. Ventral surface with four longitudinal
                                        rows of groups of glands
                                                    Adenogaster Lss. (49)
                                k_2. No ventral glands.
                                    l_1. Anterior circular ridge very high ;
                                            vesicula seminalis very long and
                                            winding skeinlike outside the
                                            cirrus sac
                                                Glyphicephalus Lss. (49)

l_2. Anterior ridge not noticeably high ; vesicula seminalis
not skeinlike   Pleurogonius Lss. (Fig. 121) (49)

i_2. Ovary behind testes, of which about fifteen are present, arranged
in two longitudinal parallel rows   Charaxicephalus Lss. (49)

h_2. Anterior circular ridge without ventral indentation ; intestinal cœca
with numerous side projections; testes and ovary deeply lobate
in hinder end of body.

i_1. Hinder end of body truncated or concave ; cirrus sac long and
with vesicular seminalis extending the greater part of the
length of the body   .   Cricocephalus Lss. (Fig. 122) (44)

i_2. Hinder end of body rounded ; cirrus sac in transverse plane
Pyelosomum Lss. (Fig. 123) (44)

g_2. Anterior end not set off from rest of body.

h_1. Longitudinal ridges or rows of glands on ventral surface; testes in
same transverse plane in hinder part of body.

i_1. Three rows of glands on ventral surface ; intestinal cœca long
and without projections ; ovary between testes: in birds
Notocotylus Dies. (Fig. 124) (44)

i_2. About fifteen longitudinal ridges on ventral surface ; cirrus sac
very large : in intestine of cetaceans
Ogmogaster Jäg. (Fig. 125) (3)

h_2. Ventral surface without ridges or rows of glands.

i_1. Yolk glands laterad of intestinal cœca in hinder portion of body;
testes in oblique plane.

j_1. Ovary between testes ; intestinal cœca very narrow ; uterus
extends to end of body : in birds
Stictodora Lss. (Fig. 126) (44)

j_2. Ovary in front of testes ; intestinal cœca broad ; uterus in
front of ovary : in fish
Galactosomum Lss. (Fig. 127) (44)

i_2. Yolk glands on both sides of intestinal cœca in middle and hinder
part of body.

j_1. But one testis present ; ovary in front of it : in Bagrus
Haplorchis Lss. (Fig. 128) (44)

j_2. Testes in same transverse plane : ovary behind them ; intes-
tinal cœca enclose both ; body circular or oval : in Box
Mesometra Lühe (Fig. 129) (54)

(*To be continued*)

NOTES AND LITERATURE.

ZOÖLOGY.

Beddard's "Mammalia." [1] — Through the publication of this excellent manual of the class Mammalia Mr. Beddard has placed the general student under lasting obligations. The subject could hardly be more judiciously treated in the limited space of a single convenient volume of six hundred pages. In scope and general character it occupies nearly the same field as Flower and Lydekker's *An Introduction to the Study of Mammals, Living and Extinct,* published in 1891, and now necessarily in some respects a little out of date. The two works are, however, naturally constructed on practically the same plan.

The " Scheme of Classification " (pp. ix–xii) recognizes only two subclasses, the Prototheria (Allotheria, Marsh; Multituberculata, Cope), including the echidnas and the duckbill, and the Eutheria, comprising all the other members of the class. These latter are divided among the following thirteen orders:

Marsupialia,	Creodonta,
Edentata,	Rodentia,
Ganodonta,	Tillodontia,
Ungulata,	Insectivora,
Sirenia,	Chiroptera,
Cetacea,	Primates.
Carnivora,	

The orders are further subdivided into 28 suborders (of which six are extinct) and 109 families. The number of species is stated to be 3000, but this is obviously far too low an estimate, even for the existing species. Trouessart, in his *Catalogus Mammalium* (1897, 1898), listed upward of 7300, and hundreds have since been added. Doubtless 8000 to 10,000 species would not be too high an estimate for both fossil and recent.

[1] Beddard, F. E. *Mammalia.* The Cambridge Natural History, vol. x. London, Macmillan, 1902. 8vo, xii + 605 pp., 285 figs.

In the brief introduction (pp. 1–4) the class Mammalia is very satisfactorily defined; and in reference to their position as the "highest of the Vertebrates," the term "highest," in comparison with "specialization," is considered, and its use in such a connection is amply defended, since "specialization" does not necessarily imply the perfection and complexity of structure that is involved in the term "highest." "Most specialized" and "highest," and "least specialized" and "lowest" are therefore not the equivalent alternatives some writers have considered them to be, and in preferring the former to the latter as more definite and exact expressions they have not thereby secured greater accuracy of statement.

An exposition of the structure of mammals occupies pages 5–78, and deals concisely with their external form, skeleton, skull, teeth, the organs of digestion, respiration, reproduction, the brain, etc., with numerous well-chosen illustrations. The present distribution of the class and the subject of zoölogical regions is treated less satisfactorily (pp. 78–89): because the tiger "is as much at home in a tropical jungle as on the icy plains of northern Asia" is no proof that "the world cannot be mapped out into areas bounded by parallels of temperature"; because there are a few wide-ranging types it does not follow that temperature does not constitute one of the most powerful controlling influences in the distribution of life over the globe. The primary regions and their subdivisions here adopted are, however, those now most generally accepted.

Chapter III (pp. 90–95) considers "The Possible Forerunners of the Mammalia," and Chapter IV (pp. 96–104) is entitled "The Dawn of Mammalian Life"; both subjects are carefully and conservatively treated. The rest of the volume takes up the orders of mammals in their systematic sequence, from monotremes to primates. Respecting this part of the work the author says: "I have given, I hope, adequate treatment from the standpoint of a necessarily limited treatise to the majority of the more important genera of mammals both living and extinct." Such groups as the Edentata and Marsupialia are given relatively, and very appropriately, much more space than is accorded to many of the other orders. On the other hand, the Rodentia and Chiroptera, with their multitude of forms, are treated so briefly that one almost regrets that the plan of the work did not permit of an additional hundred pages or so, in order to more fully notice these and a few other groups now very briefly noticed or quite omitted. But the author has given us so much that is good in this excellent manual that it is rather ungracious to make

such omissions, doubtless seemingly necessary from the publishers' standpoint, a matter of criticism.

Notwithstanding the general excellence of Mr. Beddard's *Mammalia*, there are a few slips and misstatements that should hardly pass without notice. While generally free from typographical errors, the reference on p. 415 to "Wortman and Malkens" might puzzle readers unprepared to recognize that "Malkens" is a misprint for Matthew. As a general criticism, it may be stated that the author is averse to the adoption of most of the recent changes in nomenclature, due to the enforcement of the foundation principle of nomenclature, the rule of priority. A few of them — and among them some of the most unwelcome — have been adopted, but in most instances the author is content to say, as in the notorious case of Trichechus for the walruses: "This family contains but one genus, *Trichechus*, . . . or *Odobænus*, as the more correct term seems to be." And so on in many other instances, temporary convenience, at the cost of a vitiated nomenclature, being preferred to the slight inconvenience of introducing to the general public, and particularly to the rising generation of students, names recently established as the correct names, and which will therefore, sooner or later, become the familiar names in the literature of the subject. The conservatism of habit is thus allowed to retard progress in the attainment of a correct and stable nomenclature. Incidentally it may be added that the author recognizes only one species of walrus instead of two; which is only to be explained on the ground of inertia or conservatism, and lack of actual investigation of the point in question; for although Mr. Beddard is almost ultra-conservative in the matter of species and genera, it is hardly possible to believe that he could say, "There is but one species of walrus, though it has been attempted to show that the Pacific and Eastern forms are different," if he had actually compared the skulls of the two forms.

In his comment on the elephants he notes that (p. 221) the African elephant "has been sometimes referred to a distinct genus or subgenus, Loxodon," and later (p. 223) speaks of the Indian elephant as "*Euelephas indicus*, if the genus Loxodon is to be accepted"; whereas in reality the Indian elephant would in such case retain the name *Elephas indicus*, *Euelephas* being a synonym of *Elephas*. Judging from his treatment of the rhinoceroses (to pass over many other similar cases), the author's conception of genera is open to revision, since such groups (as well as the higher groups) are supposed to indicate degree of differentiation regardless of whether they consist of a

single species or many; and not that diverse types are to be thrown together, if they happen to have some striking features in common and are each represented by single species.

The enumeration of Reithrodontomys as a characteristic South American genus (p. 480) is probably an inadvertence, as is perhaps the statement that Capromys " is found only in the islands of Cuba and Jamaica," whereas there is a species in the Bahamas, another on Swan Island, coast of Honduras, and still another in Venezuela. It is, however, surprising to find currency again given, especially in a work of high scientific standing, to the long since exploded myth of the " happy-family " relations of the prairie dog, owl, and rattlesnake. It is also rather surprising to find the statement (p. 518) that the common mole of the eastern United States (*Scalops aquaticus*) is " a creature of largely aquatic habits," — a wholly false inference, derived apparently from the animal's unfortunate specific name.   It is also not quite true that the arctic fox (*Canis lagopus*) " is known by its bluish summer coat and pure white winter dress as ' blue fox ' and ' white fox ' respectively."   This has been so often stated in books of natural history that Mr. Beddard cannot be blamed for repeating it ; but the truth is that the blue and white phases are not altogether seasonal conditions, since at some localities, as the Aleutian and Pribilof Islands, only blue foxes are found.   Indeed the blue foxes of these islands are regarded by the latest authorities on the group as specifically distinct from the white fox.

The foregoing criticisms relate for the most part to minor matters, which do not seriously detract from the value of the work.   As would be expected, Mr. Beddard's treatment of his subject is thorough, and fairly represents the latest generally accepted views and results in systematic mammalogy, a field in which he has long been an energetic worker and a recognized authority.   The publishers have done well their part in placing before the public a needed work of great merit in pleasing form.   The paper and typography are all that could be desired, and the illustrations, abundant and well-selected (those of structural characters are mainly after Flower, Wiederscheim, De Blainville, Osborn, and others), are printed with admirable clearness.   Mr. Dixon's numerous full-length drawings are of unequal merit, but most of them are both satisfactorily artistic and effective, while some are admirable.

J. A. A.

QUARTERLY RECORD OF GIFTS, APPOINTMENTS, AND DEATHS.

EDUCATIONAL GIFTS.

Ohio State University, $5000, from Prof. S. W. Robinson, Vassar College; 10,000, by the will of Adolph Sutro.

APPOINTMENTS.

Jean Brèthes, custodian of insects in the museum at Buenos Aires. — Dr. Oskar Ebert, custodian of the collections of the Prussian Geological Survey. — T. W. Galloway, professor of biology in Milliken University, Decatur, Ill. — Professor Griffon, professor of botany in the National School for Agriculture at Grignon, France. — Dr. Maurice Jaquet, conservator of the oceanological museum at Monaco. — Dr. Fridolin Kasser, professor of botany in the Vienna Agricultural School. — Dr. Adolf Klautsch, district geologist of the Prussian Geological Survey. — Dr. Benno Kühn, geologist of the Prussian Geological Survey. — Dr. R. S. Lillie, instructor in physiology and histology in the University of Nebraska. — Dr. Lorenz v. Liburnau, docent for zoölogy in the Vienna Agricultural School. — Dr. Raymond Pearl, instructor in zoölogy in the University of Michigan. — Dr. Henry F. Perkins, assistant professor of biology in the University of Vermont. — A. R. Ruggles, assistant to the state entomologist of Minnesota. — Dr. Sommerfeldt, docent for mineralogy in the university at Tübingen. — Dr. Paul Sorauer, docent for plant pathology in the university at Berlin. — Dr. F. L. Stevens, professor of biology in the Agricultural College at Raleigh, N.C. — Dr. Robert H. Wolcott, assistant professor of zoölogy in the University of Nebraska. — Dr. Wilhelm Wolff, district geologist of the Prussian Geological Survey. — Dr. Oskar Zoth, professor of physiology in the university at Innsbruck. — Prof. R. Albrecht Zimmermann, botanist of the biological station Amani, in German East Africa.

DEATHS.

Alfred Blavy, entomologist, in Montpellier, France. — Oliver Collett, student of the Mollusks of Ceylon, at Colombo, June 13, aged 35. — John Edward Fletcher, British entomologist, at St. Johns, February 26, aged 66.

— Petrus Heude, missionary and naturalist, near Shanghai, China, January 3, aged 66. — George Samuel Jenman, government botanist, in Georgetown, British Guiana, February 28, aged 56. — Prof. Dr. A. Ludwig G. Leimbach, editor of the *Deutsche botanische Monatsschrift*, in June, aged 53. — William Neale Lockington, a student of Crustacea and fishes, and at one time a considerable contributor to this journal, at Worthing, Sussex, England, August 3, aged about 60. — John William May, entomologist, in London, June 17, aged 78. — Antonio Mori, professor of botany, at Modena, April 6. — Felix Nawrocki, emeritus professor of physiology, in Warsaw, June 3, aged 64. — David Pacher, author of a flora of Carnathia, aged 86. — Dr. P. Plósz, professor of physiology, at Budapest, aged 57. — Dr. Bernard Schmidt, docent for botany in Tübingen, May 28, aged 35. — Dr. Michael Tichomiroff, professor of anatomy in the university at Kieff, May 30, aged 54. — Charles M. Wakefield, student of the insects of New Zealand, May 11, aged 64.